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PARADE
OF THE LIVING

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A History of Life on Earth

BY

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LONDON

GEORGE ROUTLEDGE & SONS, LTD.

BROADWAY HOUSE, CARTER LANE, E.C.

1931

PRINTED IN GREAT BRITAIN BY HEADLEY BROTHERS,
18 DEVONSHIRE STREET, LONDON, E.C.2; AND ASHFORD, KENT.

TO

THOSE WHO ARE

CURIOUS

APOLOGIA

THE history of life on earth is more than a collection of shells and bones in a cabinet. It is more than a procession of changing forms and functions. It is a dramatic spectacle. One of the quaintest among human irrationalities is the belief that lower animals are blind and helpless, but that man is master of his fate. As a matter of strict truth, however, man has arrived at his position in the world quite as unconsciously as the oyster at his. A doctrine of design applies no more reasonably to the one than to the other. In writing this story of lower creatures the author has used the vocabulary of man simply because that of oysters is unknown to him. His expression is confessedly askew with the bias of humanity, because the very language of man is shaped to the desire that existence may have a purpose. Unfortunately nobody knows much about the motives in nature or in man, but it is clear that only through our sublime self-esteem do we cut ourselves off so completely from our lower relatives. Whatever may be the causes, it is obvious that the conflicts of the humble protagonists in this drama are essentially the conflicts of civilized man. To recognize the kinship of all who walk in the flesh is but to recognize a fundamental truth. The pathetic fallacy lies not in this but in the egotism that scoffs at it.

Stuart Sherman once said " the great revolutionary task of nineteenth-century thinkers was to put man into nature. The great task of twentieth-century thinkers is to get him out again." This author would like to suggest in all humility that it would be more felicitous to leave man where he is and to try to understand his position. To do this we must know the forces that carved his destiny and the materials whence he was hewn. If in this story the reader can follow the stream of human significance flowing through the facts of organic development, if he can be absorbed by the drama of the greatest spectacle in the whole realm of nature, the author will feel he has not too miserably failed.

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PART I

I

CHILDREN OF THE SUN

A SEA whose shores no eyes have ever seen, whose depth no instrument can fathom, whose waters no scientist can analyse—such is the sea of space. Nothing can be as empty and cold as the gulf wherein our destinies are immersed. Star worlds, like fish in schools, drift through the void, star worlds as large as our sun and many times larger, in schools of hundreds of millions. Unlike a school of fish, whose direction may be changed by a whim of the leader, whose organization may be destroyed by the rush of an enemy, whose fate is in the hands of a shifty environment, the stars in their galaxy move with the majesty of perfect orderliness. From the smallest satellite slave of the smallest star to the largest super-galaxy of worlds in space, everything bows to the first law of nature. Chaos and caprice do not exist.

Hundreds of millions of stars are visible to the powerful eyes of astronomy. They are grouped in the shape of a thin watch whose greatest diameter is ten to fifteen times the thickness. Light consumes perhaps as much as one hundred thousand years in travelling along the equator of the disc, light which moves at the speed of more than 186,200 miles in a second can circle the earth seven times during one beat of the human pulse. The Milky Way, where the stars

seem more thickly grouped, reveals our position in the galaxy. We are near the outer edge, and when we see the clotted light of the Milky Way, we are looking through the long diameter of our universe. Many kinds of stars are brothers of our sun, stars of incandescent gas, dark dead stars burned to cinders, single and multiple stars in open and closed clusters, stars in vast irregular clouds, as well as much nebulous fire-mist of uncertain character. Everything is in motion, not only the galaxy as a whole, but all the minor states in the republic of suns.

Our own sun, with its coterie of devoted attendants, wends its way through the swarm, held by the mysterious power that keeps the worlds in our universe together, and pulls them ever into more intimate association. Copernicus violated the vanity of men when he proved the earth a mere satellite of the sun. Modern astronomy goes further and paralyses the imagination. Our sun is but one among hundreds of millions. And the hordes of visibly blazing suns are probably not all. Dead stars, like dead men, may be more numerous than live ones. Outside our galaxy are other universes, similar to our own in shape and size, so distant that their light reaches us only after a million years.

Like jetsam in an ocean current, the sun and her small family voyage through space and time, with man a microbe on a drifting fragment, a molecule in an infinity, a moment in an endless day, lost in the cosmos, his purpose as obscure as his destination. Fortunately

for his peace of mind, man's philosophy does not often rise to astronomical heights. The largest star in the firmament might disappear for all he cares. His concerns are down on earth with his problems. Yet he may well take some interest in the universe without. From a catastrophe in this universe his life began, and from a similar catastrophe it may some day end.

No modern scientist doubts that all the planets, moons, asteroids, meteors, and comets in our solar system were born of the sun. The blood relationship of earth and sun has been proved by the spectroscope. This instrument breaks up the white light of the sun into a series of bands. Each band denotes the presence of a definite chemical element. The composition of the sun is thus known to be very similar to that of the earth. More than forty elements known upon earth are present in the sun. The other planets and their moons, the meteorites and the comets, show no elements foreign to earth. The kinship of all members of the solar system is a clear fact.

The birth of the earth and her sister planets has inspired several guesses. For many years the views of the French astronomer, Laplace, were accepted. He thought the parent sun a nebula of hot gas with a diameter of more than five billion miles, sufficient to include the orbit of the outermost planet, Neptune.*

* The trans-Neptunian body recently discovered by investigators at Lowell Observatory, and announced as the planet predicted by the late Percival Lowell, has not, at the present writing, been accepted as such by all astronomers.

This mother nebula rotated slowly, shrinking and gaining speed as it cooled. A ring of gas was eventually detached, which condensed into a gaseous spheroid, rotating about the sun. Thus was the first child, the planet Neptune, born. Again and again rings were thrown off the contracting sun, and Uranus, Saturn, Jupiter, Mars, Earth, Venus, and Mercury in turn took up a separate existence. In similar fashion the planets gave off rings that collapsed into moons, rotating about the planets as the planets rotate about the sun.

But alas for theories that germinate in the minds of men! They wilt in the bright light of advancing knowledge. Today any undergraduate can know what Laplace could not have known, that in the evolution of a gaseous nebula, the high activity of the molecules would have scattered the materials of the rings in space before the rings could form; that even if the rings had formed, they could not have condensed into spheroids. The lighter gases of the earth's atmosphere would have rushed into space, overcoming gravity with the indomitable energy of their molecules. Furthermore, the gas in the earth ring would doubtless have cooled to a solid long before the time when the gaseous ring was thought to have formed.

The nebular hypothesis has other failings. It is too simple to explain the complexities of movement in the solar system. There is much doubt that the mother nebula could have detached a ring before it had shrunk well within the orbit of Mercury, the innermost planet.

If the views of Laplace were true, the satellites should revolve in the direction of the rotation of their planets. But one moon of Saturn and two moons of Jupiter revolve in the opposite direction. The planets should be rotating faster than their moons, and the sun fastest of all, because with cooling and contraction the speed of rotation should have increased. Yet Phobos, the inner satellite of Mars, circles the planet three times while the planet turns on its axis but once. Jupiter, with less than one-thousandth of the mass of the solar system, has most of the movement, movement which, according to the theory, should be invested in the sun.

Thus it is that the nebular hypothesis must blush before the facts of modern physics and astronomy. But youthful sciences grow vigorously and old tissues of theory are replaced by new. The nebular hypothesis will take its place in the history of science as a boon to progress through its very errors. For man must have a cosmogony, and false cosmogonies, like false gods, drive the thoughtful to search for the ultimate truth.

Perhaps the greatest contribution to theoretical science since the Darwinian renaissance in biology was the planetesimal hypothesis of Professors Chamberlin and Moulton of the University of Chicago. Like the savants before them, they believe the earth an offspring of the sun, but unlike Laplace, they allow her not only a mother but also a father. A star is thought to have passed near enough the ancestral sun to exert a gravitative pull. Even now the sun is belching

incandescent materials from its surface almost three hundred thousand miles into space and at the rate of more than three hundred miles a second. Normally these materials fall back into the sun. But at the time when the solar system was destined to come into being, great arms of this eruptive stuff are thought to have been forced from either side of the sun and bent into spirals by the attracting force of the visiting star as it passed by. The sun was not strong enough to pull back its substance after the star had moved on, so that the ejected matter in the spiral arms remained detached. In the cold of space this gaseous material quickly froze to solid bodies that took the form of knots, some large and some small, with many finer particles between. All bodies thus formed revolved in elliptical orbits about the sun.

In time the large knots in the spiral arms collided with the smaller particles because of the eccentricities of the elliptical orbits. Slowly the large knots grew larger, absorbing by means of their superior gravity the lesser material in their paths. Each knot was the fore-runner of a planet, and grew by sweeping up the smaller planetesimals. The satellites, growing in the same way, never became as large as the planets because they were smaller at the start. With every collision the planetary orbits were modified from the elliptical towards the circular. It is a striking fact that the largest planets, Jupiter, Saturn, Uranus, and Neptune, which are supposed to have absorbed the greatest amounts of planetesimal material, have nearly circular

orbits, whereas the insignificant planetoids, by-products of the solar system, move about the sun in highly eccentric pathways. Variation in the manner and rate of infall of the planetesimals accounts for the fact that some planets spin slowly and others rapidly, and that three satellites move in a retrograde direction.

The planetesimal hypothesis is the best cosmogony modern science can offer because it best explains the known facts of the solar system. But modifications of certain details have been argued. Barrell maintained that planetesimals of considerable size must have fallen upon the solid earth nucleus with force and rapidity enough to melt the growing planet. Jeans and Jeffries believe the planets and their satellites were gaseous and liquid from the beginning. The advocates of the planetesimal hypothesis insist that the earth grew slowly, predominantly cold and solid throughout its history.

Unfortunately, vital facts necessary to prove any of these assumptions are buried beneath the accumulated rock débris of later eras. If the earth had condensed from a liquid, we might expect to find remnants of the original crust that formed over the cooling globe, like slag in a blast furnace. Nowhere has the prying eye of science made such a discovery. If the earth had been built slowly from cold planetesimals, we might expect to find traces of such material. But nature yields no easy victories; change has obscured or destroyed the record. With our present knowledge

we can know but one thing with certainty, that the earth could not have been both liquid and solid at the same time. In a wilderness of speculation the path of truth is hard to find. Yet time and its revelations may some day point the way.

For the present we must be content with two stories about the early history of our planet. One or the other may eventually be proved true, but it is not impossible that both are false. Those who believe the earth solid from birth see it first as a knot of solid material about one-tenth the present size. Slowly this nucleus gathered to itself the star-dust in its path. The infalling planetesimals were not large enough to liquefy the earth, but the heat of their impact liberated some gas. As the globe grew larger its gravity was able to prevent the escape of part of this gas. The blanket of the atmosphere began to form. At the same time, decay of radio-active minerals generated heat, internal pressure in the growing earth increased and developed more heat, easily fusible rocks were changed to liquid in pockets, volcanoes were born, more gas was given to the atmosphere. The water vapour in the young air was multiplied until some of it condensed as rain. Pools of water stood on the earth's rocky surface. Low areas were eventually filled with water and the oceans began their long careers.

Life came as a natural result of favourable conditions. Its past has been a long struggle in the slime. Its future may be glorious beyond even the dreams of the past. For life will go struggling on as long as it is

allowed to exist, and the end of present conditions is lost in the future.

Those who believe in a formerly liquid earth tell a sadder tale, of an earth that yesterday was steaming under the white heat of Hades, and tomorrow will be as cold and dead as the moon. The whole solar system is running down. Life is but lightning flashing in a troubled night, only to vanish with the day. We now enjoy the special conditions necessary to our existence: enough air and water, temperature of the correct range. But the earth is stiffening in death. It will freeze to the absolute zero of space Man and all his lower relatives will breathe no more. The sun and her children will continue to swing through space and time, the past but a memory of glory lost, the future devoid of hope. At present we cannot know, but time may yield the truth. Meanwhile lovers will go on with their love, politicians with their wars, and scientists with their theories.

II

A GHOST WALKS

LIVING things are the result of a special, perhaps a unique combination of conditions. They stand small, weak, and alone in a wilderness of the dead. Cruel forces beat upon them and reduce them whenever possible to the unleavened clay from which they sprang. For however unusual the creation of life may be, its destruction is a daily tragedy. That which animates us is held by a fragile thread. Drop us fifty feet and the thread is broken. Change to any great extent the nature or the amount of heat, air, and water on the earth, and all life will pass away. Some stars are more than 10,000° F. at their surfaces; space is —459° F. Yet living things as we know them cannot exist long in temperatures above the boiling point (212° F.) or much below the freezing point (32° F.) of water. Most plants and animals require a far more restricted range than this. The earth is just far enough from the sun to catch the life-giving amount of heat and just large enough to hold the blanketing vapours that preserve it. The same is true of air and water; any more or less, any great difference in constitution, and the pulse of life would throb no more. Many astronomers believe that the probability of a duplication of all these conditions on another celestial body is

not great. We are puppets in the side show of the cosmic circus, creatures of chance, for chance built the show house and modelled the actors, and may some day destroy both.

Despite the irregularity and uniqueness of our existence in a dead universe, life is so interwoven with the clod it animates as to elude satisfactory definition. "Life," said Aristotle, "is the assemblage of the operations of nutrition, growth, and destruction." "Life," said Spencer, over two thousand years later, "is the continuous adjustment of internal relations to external relations." Many other definitions could be cited, but they are all unsatisfactory because they do not describe life but the properties of living matter. We do not know life any more than we know sound, light, heat, or electricity. We merely know something of how it acts. To attempt to describe life is to make ignorance flower in verbiage.

On the other hand, it is only the romantic who think of life as an unfathomable mystery. The mystic, who believes life an unknown and unknowable force that transcends the nature of matter and energy as manifested in the material world, is not so much concerned with truth as with his own hopes and fancies. We know life not as a principle but as a process.

The twentieth century sees all science agreed on one point, that nothing in nature is stationary. The stolid earth is stolid only to the eye that sees too briefly: the face of earth is ever though slowly changing its expression. Plants and animals march through

time in diversifying pageantry. The evolutionary changes so clearly demonstrated for the organic world by Lamarck, Darwin, and their successors are now with equal lucidity being demonstrated by modern physicists and chemists for the basic units of matter. Atoms are complexes of protons and electrons, many elements possess isotopic variations within themselves, certain heavy compounds are in constant flux. Matter and energy alone seem indestructible. For a brief moment a bit of matter and energy is shaped in a form peculiar to a given plant or animal. The organism dies when its form is destroyed, but the matter and energy are given up intact, perhaps to animate some other creature at some other time, and still later some other creature, *ad infinitum*. Here is physical immortality at least.

Out of the limbo of discredited beliefs the ghost of spontaneous generation rises to haunt the reflections of the scientist in search of origins. To be sure he rises only occasionally and meets scant hospitality when he does, for remembrance of the evil he performed when alive has survived his demise. It was he who deluded some of the finest minds of the ancient world, Aristotle, Lucretius, Virgil, Ovid, Pliny, and he who misled the poets, philosophers, and naturalists of the middle ages. Through him Von Helmont's famous recipe for the creation of mice was conceived, that if to a pot of dirty linen a few grains of wheat or a piece of cheese are added, the desired

rodents will come forth. In the absence of the will no less than the instruments for exact observation, man unanimously believed in the spontaneous production of living things from lifeless materials. Decaying carcasses were thought to breed insects, bad meat to give rise to maggots, rain water to animalculæ, freshly fractured rocks in quarries to toads, a horsehair in a tumbler of water to a live eel. One medieval Italian soberly announced the results of his researches, that timber rotting in the ocean gave birth to worms, and they in turn to butterflies, that eventually blossomed into songbirds.

The integrity of the doctrine of spontaneous generation was not seriously questioned until late in the seventeenth century, when Francesco Redi discovered that maggots do not develop in rotten meat unless flies are permitted to lay eggs there. The maggots that every one believed to begin life without a parent were traced to the fly eggs. Aided by the discovery of the microscope, Spallanzani, Pasteur, Tyndall, and others showed that the universally credited examples of spontaneous generation were merely crude conclusions from crude observations. Gradually it became the belief of the scientific world that since no living creature could be shown to come directly from lifeless substances, all living creatures must be preceded by living parents. This assumption, expressed in the famous dictum, "*omne vivum e vivo*," is the doctrine of biological science today.

But here the ghost of spontaneous generation rises, for life must sometime have had a beginning; sometime the dead must have quickened. It is generally believed that the earth was not always inhabited by living things, that only after proper conditions had been evolved on her surface, could life have come into existence. Most scientists will admit that life must first have developed, either on this or on some other planet, directly from lifeless material. "All life from the living" must have had at least this initial exception. It is logical enough to ask if what happened once may not happen again, if live creatures may not even now be raising their bodies from the dead muck, but so slowly or in such small units as to thwart detection. It may be that even the prototrophic bacteria, who patrol the boundary between the worlds of the living and the dead, are powerless to subdue the creative force in nature. Nobody knows, but the speculative scientist will not reject for the present a process he is forced to accept for the past, merely on the assumption that it cannot exist because he can neither see it working nor repeat it in his laboratory. He looks for facts which suggest—if they do not prove—that the process may be a possibility on the earth today.

Most textbooks and teachers dismiss too briefly the comparison of living and lifeless matter. They are content to stress the differences and minimize the similarities. It is true that in most cases the size of inorganic bodies such as atoms, oceans, and suns is

almost without limit, whereas plants and animals are restricted in this regard. The same is true of form; lifeless bodies show all varieties of form, but every live organism is definitely restricted by laws of heredity. A house cat may wail for the sinews and claws of a lion, but he can never have them. The materials of the dead world are the ninety-two chemical elements thought to exist on earth, whereas living things must be content on the whole with only six in various arrangements. Most dead materials are of low organization, most living creatures of high—cells grouped into tissues, tissues into organs, all unlike but held together by mutual interdependence. It is, furthermore, often said that the vital phenomena of growth, adaptation, and reproduction have no counterparts in the mineral kingdom.

Such are the generalizations. They erect a formidable barrier between the quick and the dead. Like most generalizations they neglect the exceptions, which in this case are certainly the most interesting and perhaps the most significant elements in the comparison. Heraclitus long ago compared life to a flame. It would seem at first that one of the most characteristic properties of living substance is the way it sustains itself by borrowing matter and energy from its environment. Yet the burning of a candle is an almost exact parallel. The flame takes oxygen from the atmosphere, transforms it, and gives off heat and light. In the same way plants and animals take food from their environment and with its aid release energy

in various forms. The substance of an egg is changed before the child is born, the flesh and bones of the child are completely replaced by new material before maturity is reached, yet the same individual persists throughout. In one sense we are not, in another we are the same people of our childhood. The flame sustains its personality in much the same way.

More significant than the nutrition of a flame are the remarkable phenomena of diffusion and osmosis, common to both lifeless and living matter. Salt placed in a tumbler of water will dissolve and spread slowly throughout the water by the process of diffusion. Diffusion occurs as a result of pressure differences in the tumbler. Molecules of the salt move from positions where the pressure is greater to positions where the pressure is less. The water molecules, on the contrary, pass from places of lesser to places of greater pressures. As a result pressure is equalized and the salt is dissolved and distributed throughout the water in defiance of gravity.

Osmosis was discovered in 1748 by the Abbé Nollet when he plunged a pig's bladder full of alcohol into water, and observed that the water seeped into the bladder more rapidly than the alcohol escaped, with the result that the bladder enlarged. This process of a less dense solution passing through a membrane towards a denser solution is called osmosis. It is osmotic pressure that lifts water from the soil to the topmost twig of the highest tree. Animal digestion is largely a process of breaking large molecules of food

into small molecules so they may be absorbed in the intestines through the physical processes of diffusion and osmosis. In fact these two processes are the foundation upon which the elaborate structure of vital phenomena is built.

Certain mineral substances in concentrated solutions, when they come in contact with other solutions, form membranes that resist differently the passage of the water and the substances in solution. Thus if the soluble salts of calcium are placed in contact with solutions of alkaline carbonates and phosphates, an osmotic membrane will form over the surface of the immersed salts. Dissolved substances in such a membrane exert pressure on the confining walls, distending them and increasing their volume. More water rushes in through the permeable membrane so that the mineral structure changes its form in very much the same manner as a growing plant or animal.

Some remarkable work has been done on the behaviour of osmotic growths by Dr. Stéphane Leduc of Nantes. Such a growth absorbs nourishment from the liquor in which it exists. New material is assimilated not as in a crystal, by external addition, but by intussusception, that is, by addition of new molecules between the molecules of the original material. It gradually becomes many times heavier than the mineral " seed " from which it started, and the medium in which it grows loses an equivalent weight. The substance absorbed by the growth undergoes chemical changes during assimilation just as the

substances assimilated by growing plants and animals. Certain mineral "foods" may be taken, others rejected; waste products are excreted.

By varying the materials and the concentration of the solutions, Dr. Leduc made osmotic growths that resembled a great variety of living things. Algæ, mushrooms, grasses, seeds, leaves, flowers, corals, clam shells, and many other types of organisms were faithfully reproduced in form, colour, texture, and structure. Some of the mineral mushrooms were actually mistaken for real fungi by experts.

Many osmotic growths swam about in the mother liquor under the stimulation of the slightest disturbance in their environment. Many underwent rhythmic movements connected with their nutrition. Some reproduced crudely by budding. Under certain circumstances the vitality of a faltering individual was rejuvenated, wounds were healed much as in live tissue. With age the membrane of an osmotic growth thickens, growth slows down and finally stops when the osmotic force in the membrane is exhausted. As in a child whose cells are young and under high osmotic pressure, the young osmotic mineral growth is plump and well formed. With increasing age flaccidity overtakes the cells of both man and mineral. Death comes ultimately to both and with it the decay of form and structure.

If we now return to our original postulate, that life is known only as a process, it is clear that the line

between the living and the dead is not as clean-cut as most people suppose. Osmotic growths, in simulating the vital phenomena of nutrition, growth, form, structure, and sensibility, lie very near the boundary of the two worlds. Then, too, whereas protoplasm, the life jelly of all creatures, has never been produced artificially, many organic substances such as urea can be made in the laboratory without the assistance of plant or animal materials. These and many similar facts show that the living and the lifeless are really not so very different. They are sisters under their skins.

It is here that Dr. Leduc and others raise once more the question of spontaneous generation. Although osmotic mineral growths do not contain albuminoids and proteids and therefore cannot be compared in chemical complexity with living things, yet they do elaborate dead matter into the characteristic forms and structures of plants and animals. They do it as live things do it, through the physical forces of osmotic pressure and diffusion. Modern chemists and biologists have failed to create a living organism, but they have succeeded in duplicating from the mineral world many of the processes and structures and some of the substances which not so long ago were thought to be the exclusive possession of living matter. It is not unlikely that in the remote past when life first came, nature went through the same experiments in her own laboratory, but carried them further to the creation of living organisms. It is not impossible that in the oceanic depths the same process is now going on.

Nobody knows much about conditions during the remote past or in the ocean troughs today. The ingredients that synthetic biologists have failed to discover must have been present when life began, and may still be present.

Here is the basis for a new concept of existence. Elements, compounds, minerals, rocks, plants, animals, man, may all be parts of one giant organism. Modern research is slowly building a basis for belief in the continuity of the evolutionary process from the simplest to the most complex forms of matter. The kingdoms of plant and animal merge along a shadowy boundary. Nobody would try to get coleslaw from a cow or milk from a cabbage because cows and cabbages are extreme types and not easily confused. But certain unicellular organisms so blend the properties of plant and animal that they are claimed by both botanist and zoölogist. Thus also merge the realms of the living and the dead. The chasm between life and death, that last great obstacle to a sound doctrine of scientific pantheism, is being removed. A man is not much like a stone, but his vital processes are almost the same as those of osmotic mineral growths. This similarity suggests that the doors between the domains of the living and the dead may swing both ways.

III

SHAPES IN THE DARK

NOBODY knows how life first began, nor where, nor exactly when. Since we cannot be sure that life is not toiling out of the chaos of dead matter under our very eyes, we must remain perhaps forever ignorant of the event of a day whose sun went down over five hundred million years ago, when the first live thing was born. In the beginning both plants and animals were probably nothing more than bits of animated jelly. It is not likely that they could have made any noticeable impression in the sea muds which became their tombs. Even if they had succeeded, a half billion years of turmoil in an afflicted globe would have been enough to destroy their meagre epitaphs.

We do not know the initial stages in the history of life any better than we know the initial stages of the evolution of the earth. Emerson once said that " everything in nature is engaged in writing its own history." This is true, but time and tide have destroyed many records. The cosmic history of the earth was written in fire against the primordial night. Not until long after the globe had become a separate entity in the solar system, not until she had acquired an atmosphere and an ocean, did she begin to write history that can be read with certainty. This story of

the rocks covers scarcely half a billion of the three to five billion years of the earth's existence. And so with life, the beginning was written in water. Not until creatures had grown to a size observable by the crude vision of man and his microscope, not until they had developed skeletons that could resist decay and become fossilized while their mud sepulchres were turning to stone, did they leave any certain records. The parade of living things through time began in a way we can never understand, in an age we can never know, just as it will end in a manner nobody can foresee, at a time that is lost over the dark horizon of the future.

The oldest rocks laid bare in the crust of the earth tell a tale of transition. They record events that happened after atmosphere and ocean had been born, but before the comparative tranquility of later periods had been established. The record is best known in the vicinity of Lake Superior where rocks formed during this early time are widely available for study. The Archaean era, as this time is called, was of immense duration, nearly one-third as long as all subsequent time to the present. We know relatively little about it, because of the turmoil of its days which complicated and obscured the record, because of the recurrent turmoil of later days which blurred and erased still more.

The entrails of the young earth stirred frequently in nervous unrest. Vast quantities of ash and lava were spewed upon the surface through fissures and

volcanic cones. Granite ulcers ate their way towards the outer crust. Occasionally respite was granted a portion of the surface, when quiet waves lapped quiet shores. But during most of the time over most of the earth, the demons of the underworld were bringing their hell to the surface. At some time during this era, nobody knows when, the day of days broke over a troubled world. At last the restless energy of nature was destined to take shape, meaning was to rise from the blind struggle of physical forces. Something stirred in the Archæan muck and the first creature emerged.

In the absence of any information about the prototype of life, the imagination is not hampered with facts. It is controlled, however, by probabilities. It is improbable that these creatures were much like any living plant or animal. There is a vast chemical and dynamic gap between magma which constitutes the bones and sinews of the earth, and protoplasm which is the physical basis of all living things. Perhaps life went through pre-cellular chemical stages of gaining complexity before it attained a form comparable to any of the forms in which it is clothed today. Nobody knows. The question is largely academic and futile.

There is some reason to believe that the earliest organisms were more like plants than animals. But here too we are confronted with the difficulty of framing definitions that will keep the two great kingdoms separated. Many creatures alive today combine

some of the most typical characteristics of both plants and animals. Ordinary plants possess green colouring matter, animals do not. Yet some plants such as mushrooms and toadstools lack chlorophyll, and some animals such as certain protozoans, worms, and hydrozoans, possess it. Not all plants are rooted to the ground, not all animals are free-moving. A few plants are as sensitive as cats, a few animals are as phlegmatic as cabbages. Most plants live on gases and liquids taken from the air, earth, and water about them, but a few are as carnivorous as the most bloodthirsty animal. Most animals are parasites on plants because they cannot live without materials found only in the bodies of vegetable organisms. Although a few animals escape this general limitation, they are decidedly exceptional. Like plants the first creatures lived directly on materials taken from their lifeless environment. There was nothing else for them to eat, excepting each other, and if they had done that there would be no discussion of the problem today.

The earliest organisms probably lived for millions of years in a subcellular or unicellular condition, eating the mud and drinking the water of their primeval sea. For they must have lived in the sea or in large lakes where sufficient moisture was continuously present. Here they were protected from the parching winds and the hot sun of the land which would have dried up their tiny bodies and snuffed out their little lives in an instant.

Eventually life must have developed to a stage of

complexity comparable to living bacteria. With the exception of the poorly understood filterable viruses (that cause certain obscure diseases in man and are thought to be organisms so small that the highest-powered microscope cannot detect them), bacteria are the smallest and simplest creatures known. They are life reduced to very low terms. All are invisible to the naked eye. All reproduce by simply dividing in two, but only after they have captured enough food and grown to a proper size. They live everywhere any other organism can live: in water, on land, on dust in the air, and in some places such as subterranean oil pools hundreds of feet below the ground, where no other creature has ever been found. Some must have oxygen, some can live only in an absence of oxygen, others eat iron, sulphur, and a host of additional materials.

If the bacteria are really a survival of an early fashion in living forms it is hard to understand why they should have remained primitive while æons rolled over their heads and relatives climbed the heights of attainment. But there is no accounting for the vagaries of fortune or the peculiarities of taste. They have seen the rise of stronger, more intelligent races than their own, but they have also seen the fall of such races. In their devotion to simplicity, the bacteria have won a long life if nothing else.

No undoubted fossil remains of bacteria have ever been found in the oldest rocks. Their presence in the

Archæan era is inferred from the vast quantities of limestone, graphite, and iron ore of that time. Certain living bacteria are believed by some to take calcium carbonate out of sea water and deposit it as a limestone ooze on the sea floor. Some of the earliest limestones may have originated in a similar way, although many were formed, as in later times, through purely chemical agencies. Graphite is a kind of carbon, related to coal, and implies the presence not only of bacteria but also of higher vegetation for bacteria to work upon. Like limestone, graphite may be produced by chemical means, but such quantities as occur in the Archæan formations strongly indicate the presence of plants. The same is true of the iron ore; much is formed by iron-eating bacteria that draw iron from sea water and deposit it in an insoluble form on the bottom.

Not until much later, after the dawn of the Algonkian era, did life leave any direct evidence of its existence. The earth had been slowly settling into more placid ways. Volcanoes growled less frequently, rivers quietly dropped their muds into the sea. It is true that a great ice sheet scoured the old land surface in Canada, that countless sub-oceanic lava flows brought the richest copper deposits in the world to northern Michigan, but on the whole the Algonkian world was calm and friendly to life.

It was then that life began to record itself in fossils. The record is meagre, some of it is questionable, but no one can doubt the authenticity of certain Algonkian remains. After æons of struggle with wind and wave,

in the face of heavy odds, life won a great victory when a simple organism built a skeleton of lime and toughened its flimsy flesh against the beat of hostile forces. These oldest undoubted fossils were found near the bottom of the Algonkian formations at Steep Rock Lake, not far from Port Arthur, Ontario. They are horn-shaped masses from an inch to over a foot in diameter. Some authorities class them with sponges, others relate them to the lime-secreting algæ of later Algonkian time. In Montana near the close of the era, conditions were especially propitious and the lime-secreting seaweeds grew to large size in inland lakes long since drained to make way for the Rocky mountains. With them were many worms that left their burrows in the muds near the ancient shores. Other alleged fossils have been described—crustaceans, protozoans, bacteria—but they are not above certain suspicion. Recently some interesting microscopic markings in Algonkian rocks from Michigan have been described by Dr. John W. Gruner as the fossil remains of bacteria and blue-green algæ. Scientists are not agreed on their authenticity because the rocks in which they occur are so altered that no one can be sure of their story. The "fossils" may be genuine remains of primitive plants, but they may equally well be frauds of the mineral world.

The gap in our knowledge of life from its beginning to the time when creatures grew large and strong enough to leave a fossil record is the greatest hiatus in man's knowledge of geological history. Over

one-third of recorded time had ebbed away before live creatures left imperishable signatures in earth history. These creatures came ready made, a full-fledged lime-secreting alga and a worm, apparently not very different from the lime-secreting algæ and worms that live today. We can only guess at their histories. Even if we start with the assumption of primitive bacteria, it is a long step to a lime-secreting seaweed. For somewhere in the evolution of the second from the first, chlorophyll, the green colouring matter of plants, had to be developed. Next to protoplasm itself, chlorophyll is the most wonderful substance in nature and the most mysterious. With it plants utilize the radiant energy of the sun to manufacture starch from carbon dioxide and water. Not until starch was made in living bodies could protein be made, and not until both were at hand in the bodies of plants could animals come into existence. Animals must have both starch and protein, and since they cannot make these for themselves they are dependent upon plants, the ultimate source of supply. The worms in the Algonkian mud built live protoplasm out of the dead protoplasm of the plants they ate. In making their bodies of albuminoids and proteids, they plumbed the depths of chemical complexity. The most brilliant chemists can neither repeat nor understand their accomplishment.

From the height of human self-sufficiency, a simple seaweed and a worm do not seem like much of a showing for such an imponderable length of time.

Yet these creatures indicate as great a victory of vital energy over the first half as does the presence of man over the last half of recorded time. They were but shapes in the dark, yet ordained soon to emerge into a brighter day at the head of a procession that spread with abundant triumph over the whole earth.

IV

WHEN THE LAST WERE FIRST

LYELL and Darwin thought of the geological record as a history written in a changing dialect by a careless historian. Of this we possess but one volume relating only to part of the globe. Just a few chapters in the volume have been preserved and of them only a few lines on each page. The rock record of the earth and her inhabitants is both confused and mutilated.

Repeatedly in the past lands stood high and suffered erosion. Countless millions of tons of rock débris, countless millions of creatures were buried in the deep ocean troughs. There they were hidden, perhaps for ever, from the eyes of man. Then, too, countless plants and animals must have lived to whom fate did not grant even that miserable shred of immortality, the preservation of their skeletons. For many organisms must have lived that had no skeletons, only the perishable jelly of their flesh. When life went out of them, decay crept in and devoured not only their substance but also the very record of their existence. Of those creatures with hard parts capable of preservation, only a few were sealed from the acids of disintegration which seek out shells and bones as well as protoplasm. And many escaped

obliteration by decay only to be destroyed later by the writhings of an afflicted globe.

Such rare accidents are the fossil relics of past days that the lost pages from the book of life are less significant than those that have been preserved. And each year brings new discoveries that prove the record not nearly so faulty as our knowledge of it. Most remarkable of all, perhaps, is that in the face of the complexity of the simplest things in nature, science has progressed so far in unravelling the tangled skein of the earth's history.

Although our knowledge of the Archæan and Algonkian eras is fragmentary it is enormous compared with our knowledge of the events that directly followed. Throughout the world lands were lifted high above the sea at the close of Algonkian time. They endured the wear and tear of erosion through ages of such duration as to rival the length of all subsequent time to the present. Plant and animal life left no fossil record. All the rock refuse worn from the land by wind and weather was washed by rivers into the deep ocean troughs. With it were carried the shells and bones of any creature who might have lived in the lakes and streams of the land as well as those who certainly dwelt along the strand lines. No more valuable cargo than this has ever foundered into the sea.

Thus it was that when portions of the continents were worn low enough so that shallow seas not unlike the Hudson Bay of today could creep in upon the

lands, they brought with them a strange assemblage of organisms. The place as well as the manner of their origin is a mystery. From north and south marine waters flooded the regions now occupied by the Rocky and Appalachian mountain systems, then the lowest portions of North America. Slowly they took possession of part of the interior basin. Everywhere they swarmed with creatures whose shells were buried in sand and mud which were later dried and cemented into consolidated rock.

These deposits are clearly contrasted with the older Algonkian formations upon which they rest. They are less broken and gnarled because the earth had finally gained respite from the intense convulsions of earlier days. And the abundance of fossil remains everywhere separates the newer from the older rocks. In fact a new era, known as the Palæozoic, began with the advance of these seas, an era when the earth was friendly to life and when life was to win some of its most significant victories.

But life had already won scores of advantages during that dark lost interval between the Algonkian and Palæozoic eras. The brine of an unknown sea had wrought magic in the meagre bodies of seaweeds and worms. Through unknown stages, stages perhaps forever unknowable except by conjecture, the simple creatures of the dawn had been nourished into a diversity scarcely less rich than that of marine creatures today. The evidence of later periods shows well that such a diversity comes only with time of

almost unthinkable duration. How it was accomplished and through what channels is one of the unanswered questions of evolution.

Plant fossils are everywhere rare in deposits of the early Palæozoic waters, perhaps because many of the primitive plants were undoubtedly simple, devoid of woody tissue, and hence incapable of preservation. But since plants are the staff of every animal's life, there can be no doubt that multitudes must have existed to support the animals recorded in such abundance and variety. Some plants may even have adventured toward the land at this time when animals were content in the water, for plants are the trail breakers of the organic procession. We do not know, because the history of the lands of this period is lost. Not until much later did plants of any habitat leave a conspicuous display of themselves. In the beginning animals usurped the arena.

All types of animals except those with backbones were alive in the seas of the early Palæozoic era. They were the first of that vast but humble society—worms, molluscs, crustaceans, and related forms—who were destined to march through most of the journey to the present in the rear of the procession. Fishes, amphibians, reptiles, mammals, and finally man arose to head the parade, each one a little farther in the lead. Today man is so far in advance that he esteems the lowly brothers of his flesh only as possible ingredients in a shore dinner. He does not even pay them the

friendly compliment of acquaintanceship, so that it is difficult for the scientist to talk about them and be understood. Yet these creatures were veterans in the battle of life a hundred million years before any organism resembling a man was born. And man, scarcely less than the other lords of earth before him, owes some of the fundamental mechanisms of his body, some of the very blood in his arteries to the forgotten travails of this unpretentious company.

Although these lowly creatures have outlived their glory, the earth was theirs for eons without dispute. In the fecund warmth of the ancient seas they swarmed to the ends of the earth. Following shallow waterways provided by the shorelines of oceanic islands they crossed from land to land. Their remains have been found in rocks of North America and South America, Scandinavia, Russia, Siberia, China, India, Australia, even Greenland and Antarctica. But their chief claim to fame was neither their abundance nor their wide distribution. Most memorable is the fact that even at this remote time they had solved some of the most fundamental and difficult problems concerned with earning a living on earth.

From out of the past these creatures came, with a variety and a complexity beyond all promise of the few fore-runners who left a record of their existence. One-celled animals with tiny shells of limestone and spun glass must have abounded in those early seas as they abound in the seas of today. Their remains, however, have been rarely found, perhaps because of

their small size. Sponges, most phlegmatic and plant-like of animals, had already gained a safe and quiet nook in the world, from which they did not trouble to move through all the ages that followed. True corals were not among the first but they appeared before the Palæozoic era was very old. Their cousins, the jellyfishes, were there, however, and a record of them has been preserved to the present time by one of the rarest accidents in geological history. Their skeletons were ninety-nine per cent. water. By a miracle some of these escaped not only the attack of hungry contemporaries, but endured burial in mud and all the restless movements of the earth through three geological eras. Jellyfishes are one of the few animals that have left a fossil record without the aid of hard parts.

Worms were plentiful but they are poorly understood because little beyond their trails and borings have been preserved. That large group of spiny-skinned animals, lavishly represented today by sea urchins and starfishes, had just begun to develop from a few simple prototypes. Shellfish of the variety known as brachiopods or lamp shells (because some of the later ones resemble Roman lamps) were abundant everywhere. Soon after their abrupt appearance they perfected two mechanical devices that insured the prosperity of their descendants. Like most other backboneless animals, and contrary to the prevailing fashion among the backboned fishes, amphibians, reptiles, birds, and mammals, the lamp shells wear

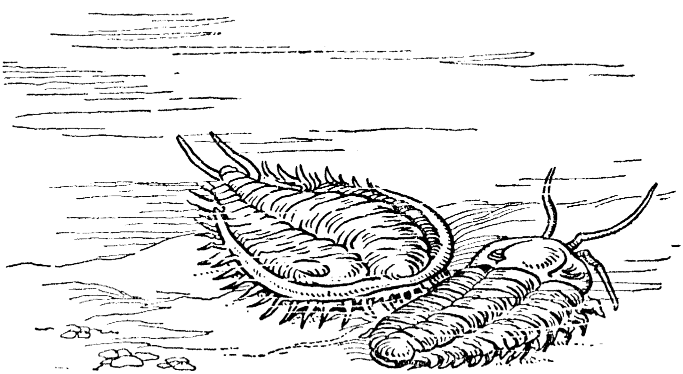
their skeletons outside rather than inside their flesh. At first they held together the two valves of the skeleton merely by the muscles of the body. Later they developed a hinge through which the valves articulated. This relieved the muscles from all work except the opening and closing of the shell. The early phosphatic shell was discarded for a limy shell of greater durability. Because of these inventions which were soon adopted by all progressive lamp shells, the race became dominant in the seas of the Palæozoic, and was able to survive competition with time and superior organisms to the present day.

The large class of molluscs, some of whose members are superficially like the lamp shells, had just begun. Shells like those of clams and oysters are unknown. Nautilus-like creatures, marked for later prominence, were rare. Snails wore small conical or simply coiled shells and were not abundant. A related type, the "wing foot" or pteropod, consisted of a simple conical shell from which a fleshy wing-like organ extended. With this the animal drove himself swiftly through the water, bringing no doubt plenty of consternation to quieter and more peace-loving citizens. Pteropods were the most abundant and the most successful molluscs of their day, but the sun of that day has set. Like many another creature, the memory of their past is more glorious than the promise of their future.

Not a few of these animals were excellent enough when compared with the simple organisms that must

have lived before them. But they fade into insignificance when compared with that great group of contemporaries, the early crustaceans. These animals, remotely related to present-day shrimps and lobsters, were the biological marvels of their time. They were the swiftest, strongest, keenest, and most versatile inhabitants of the earth through the earlier periods of

Trilobites



the Palæozoic era. They were ruled by a group whose bodies were divided into three longitudinal lobes, and for that reason called trilobites.

Because of their abundance in the older Palæozoic rocks, trilobites attracted the attention of early naturalists. There was far-flung speculation as to the manner of the beast. Beetle wings, said one naturalist; caterpillars, said another. Decidedly not, said yet another, these creatures are fossil butterflies. With the admirable patience so characteristic of the dead, the trilobite endured the tomfoolery of the

learned until Linnæus, a Swedish botanist, correctly demonstrated the relationship of the trilobite to the crustaceans of today.

Compared with a shrimp or a crab the trilobite was a simple crustacean. Compared with the worms, molluscs, and other invertebrate creatures with whom he lived, the trilobite was a highly complicated animal. Some of the earliest trilobites were primitive, and their generously segmented bodies, their small heads and tails, suggest a line of worm-like ancestors. The same stock of worms from which the trilobites were descended is believed to have given rise to the mighty sea scorpions of later times, and a related stock of the horseshoe crab who still lingers on many a modern strand. Thus the trilobite stands as the earliest monument to a creature of little repute except among evolutionists, birds, and boys with cane poles. The final turning of the worm will come when (and if) time proves right the evolutionist who believes that insects, spiders, and man himself were descended from him.

The ancestry of trilobites is entirely conjectural because these creatures appeared in full feather with the first seas of the Palæozoic era. Some of them had reached their climax and had degenerated before leaving a fossil record. Most of them were strong swimmers, but some of them crawled. The degenerates burrowed in the mud and eventually lost their eyes. All had segmented bodies covered on top with a substance similar to that of the horns of cows and the hair of mammals. Most of them could curl up like

armadillos and cover their soft vitals with the hard shell of their backs. This habit enabled the trilobite to resist weather and the attack of enemies for many long ages and kept some of them on earth after the death warrant of their race had been signed.

Although the trilobite was a small animal, he dominated the life of the ancient seas through those early periods of the Palæozoic era known technically as Cambrian, Ordovician, and Silurian. Most trilobites were about three inches in length, but monsters of over a foot are known. They were the dominant meat eaters and scavengers of their time. They were masters of the living world for ages untold, yet decline and death had been written into their destiny.

In these first abundant remains of the earth's inhabitants we see evidence of widespread advantages already gained by living forms in their struggle for security. Even the lowly sponges had acquired a variety of body styles to fit a variety of environmental conditions, and had perfected a simple but adequate canal system for capturing food and expelling waste. They had experimented with both sexual and asexual reproduction, with communal as well as independent living, and they had developed simple nervous systems and simple skeletons.

The jellyfishes and their kin had invented tentacles, mouth, and digestive cavity with which to gain food, and an effective array of stinging cells with which to avoid becoming food. Some of the worms had grown

a body of many segments, with a mouth at one end and an anus at the other. They were the first as they are the simplest animals with differentiated nervous system, special organs for digesting and excreting waste, a heart, and that bilateral symmetry which characterizes higher animals. Like the body of a man the body of a worm can be divided along its length into two parts that are mirror images of each other; lower animals are built like a wheel with hub and spokes. The lamp shells had all the advantages of their lower associates plus separate male and female sex organs, special organs for breathing, and a stronger skeleton. Snails had distinct heads with eyes and tentacles, as well as a muscular foot for locomotion and a fleshy mantle to enclose and protect the viscera.

The trilobites, however, epitomized and surpassed all the advantages gained by the others. They had a segmented body protected by a horny outer skeleton and a complicated system of muscles to operate it. They had mouth, teeth, throat, stomach, digestive glands, intestines, and anus. A muscular heart pumped blood through arteries and capillaries, and over the gills where it was purified. A rudimentary brain, a chain of nerves, organs of touch and sight, possibly also of smell and hearing, directed the animal's activity. Specialized appendages for crawling and swimming, and organs for sexual reproduction were well developed.

At the very beginning of a continuous record of life on earth nature had brought to perfection in the

trilobite the style of body characterized by the absence of a backbone. In such bodies the digestive tube lies above the nervous system and the skeleton is on the outside. For a sedentary life in quiet waters such a body is quite adequate. For an active life in streams and on the land it is weak and insufficient. When the urge to greater activity was first felt by the ancestors of the early fishes, the old invertebrate body was revolutionized. Nobody knows exactly how nature reversed the positions of digestive tract and nervous system, nor how she transferred the skeleton from the outside to the inside. We do know that while backboneless animals were luxuriating in the easy warmth of the early Palæozoic seas, the progressive among them were experimenting with a new body to meet the requirements of a sterner environment. Even in the heyday of their existence, doom for the early lords of earth was gathering in the offing.

V

A NEW THING UNDER THE SUN

SO elusive is the condition of security that although all creatures from the first have striven after it, not one has ever attained it. Even when the trilobites were at the height of power, they were harassed by enemies. There were myriad other mouths to be fed, mouths that would not have dared to open in direct combat, but which were formidable enough when applied to the common larder. Nature has never adequately provided for the prodigal output of her womb. She has made hard and narrow the lives of most of her children. To eat and to avoid being eaten is all that life offers most creatures. In the days before ingenuity was born, murder was the chief means of stifling competition. But life could not then, as it can not now, live entirely upon itself. Then as now the weak had ways of drawing sustenance from the crude but fundamental sources of nourishment. They had ways of storing it in unnoticeable or unpalatable forms. In one way or another they managed to live, and merely by doing so to make life harder for the strong.

We cannot know how much the lesser contemporaries of the trilobites contributed in this way to their downfall. We do know that a race of molluscs

developed during the Ordovician, second period of the Palæozoic era, into large and dangerous antagonists. Practically unknown in deposits of the Cambrian seas, they rose rapidly to power. Nor did they relinquish it through many of the ages that followed. Today, long after the complete extinction of the trilobites, these molluscs are still represented on earth. The cruel and bloodthirsty nautilus of southern seas is a lone but worthy survivor of this aggressive race.

In the beginning the ancestors of the nautilus (who were also the remote forefathers of the squid and the octopus) lived in long conical shells. With time their shells became curved and then coiled, but at first the straight-shelled type was most abundant and most powerful. The animals inhabiting these shells were highly organized. They possessed distinct heads with eyes and tentacles. They used their tentacles not only for feeding but also for crawling and swimming. Thus the head functioned also as a foot, an economy still popular among a large and varied group. For this peculiarity such animals are called cephalopods, a term which refers in Greek to their most striking idiosyncrasy.

Soon after birth the early cephalopods secreted small conical shells to protect their soft bodies. As they grew they extended their shells and built walls across the abandoned portions. Some fossils are several feet long and contain scores of chambers, only the outermost one of which housed the animal at the time of death. These animals not only carried their

houses on their backs but all the houses they had ever inhabited. Fortunately their shells were thin and the empty chambers were filled with a buoyant gas. Many of them were excellent swimmers.

There can be no doubt that the early straight-shelled cephalopods devoured not only much food that might otherwise have fallen to the trilobites, but many trilobites as well. They did not reach the climax of their power until the Silurian period, and after the trilobites had begun to decline, but it is very likely that they hastened that decline.

No competitor, however, no enemy, no manner of external influence can fully account for the extermination of a whole great class of organisms. Death comes ultimately from within. Trilobites had failed to keep abreast of the times. None of them had built skeletons to protect their vulnerable underparts. None of them had grown weapons of offence like the pincers of later relatives. While other creatures had been evolving bodies of greater efficiency, the trilobite had become set in his ways. Toward the end he blossomed as the rose. His majestic person was adorned with spines and pustules. But such refinement spawns in the decay of a race, even as excessive luxury in a civilization grown rotten. The blood of the trilobite was running thin and his hour was approaching. He had grown old.

Life is remarkable for many qualities but for none so much as the questing energy which drives it ever

onward. While cephalopods and trilobites were struggling for mastery of the sea, a scorpion, the first known air-breathing animal, was quietly born on a Silurian strand. Shortly afterwards a few spongy plants crept from their ancestral home in the ocean to try life on land. Most significant of all was the experiment with a new body made by the ancestors of the fishes back in the rivers of the land. When launched into the sea this body was immediately successful. The primitive fishes, first animals with backbones, swept all the field before them. And ever since backbone has had its way.

No one knows whence nor how the first fishes came. The earth is silent on the matter. No trace of their ancestors has ever been uncovered. We shall probably never have a fossil account of this momentous chapter in the history of life because the earliest backboned animals were probably not only small but devoid of any structures capable of preservation.

The living world has been combed for an organism that might suggest the prototype of backboned animals. One of the simplest living vertebrates is the lancelet, a sluggish little marine creature who spends his life partly buried in the sand along warm sea coasts. Although he possesses a rudimentary backbone, a nerve cord on top of it, and numerous gill slits, he lacks many of the embellishments of true fishes. He manages to get through life without limbs, skull, jaws, spleen, genital ducts, heart, eyes, or brain. Because of these deficiencies he has been called a prophecy of a fish,

a hopeful but unwarranted appellation. For his simplicity is that of degeneration rather than primitiveness, and his only hope is that he may sink no further.

In somewhat similar case are the tunicates, or sea squirts, a numerous group of small, attached or floating water animals. The embryo of the tunicate has a well developed rudimentary backbone in its tail, surmounted by an unmistakable nerve cord. These, however, disappear in the adult, whose only claim to affiliation with backboned animals is an elaborate gill system. So too the burrowing acorn worm, with his gill slits, remnants of a backbone, and dorsal nerve cord, is clearly a degenerate. Such animals are possibly in their racial second childhood. Their bodies may be somewhat like those of their primitive ancestors. But they shed no real light upon the origin of backboned animals.

There have also been many attempts to find the ancestor of vertebrates among the segmented invertebrates, but with little success. No known backboneless animal possesses a single one of the three essential characteristics of the simplest backboned animal: gill slits, backbone, or dorsal nerve cord. Some possess long nerve cords along their bellies. Many theories grasp this fact and turn the animals upside down. Unfortunately this brings the mouth on top of the head. The man with a theory, however, is not to be stopped by such a detail. He merely assumes that the old mouth grew shut and that a new one opened in the right place. Other theories do not capsize the animal

but assume that the nerve cord grew around the gut and that a new digestive apparatus appeared below. These and other theories are interesting chiefly because they demonstrate how very little anybody really knows about the origin of backboned animals.

Perhaps the best intimation of the origin of the early fishes lies in the method whereby a typical modern fish propels himself through the water. He advances by wriggling from side to side with the movement of a flag floating on a breeze. It may be significant that no backboneless animal of the sea travels in exactly this way. Many do not change their positions at all, but are rooted to the bottom like plants. Such are the adults of all sponges and corals, as well as crinoids, the extinct cystoids and blastoids, and many molluscs. A few, like the sea anemones, crawl a little. Jelly-fishes are weak swimmers, slaves of wind, tide and current. They spend their days as Tomlinson saw them, dimmering like sunken moons in the blue translucent depths. Crustaceans and related forms swim and crawl, chiefly by means of leg-like appendages. Squids can dart backwards by squirting water forcibly from their mouths. Only certain worm-like organisms swim with an undulating movement like that of fishes. Unlike the fishes, and in the manner of apocryphal sea serpents, they wriggle in an up and down, never in a side to side, direction.

Backboneless marine animals are the creatures of the sea in which they live. Like the sea itself they are sluggish, if not entirely sedentary. Like the rest of us

they are products of their environment. They have never needed highly developed locomotive mechanisms so they have never developed them. Because the fishes did develop such a mechanism, many authorities believe that they were a response to an entirely different environment.

The free end of a bit of flotsam caught on a rock in a stream swings from side to side with the current. This is the direction of least resistance, the only possible compromise with the force of running water and the force of gravity. The same undulating motion is imparted to the inert body of a worm clinging with one end to a rock in a stream. T. C. Chamberlin believed that the ancestors of the vertebrates must have lived in this way. In the dynamic waters of streams these ancestors, whoever they may have been, received the incentive to develop the characteristics which distinguish backboned animals from their lower relatives.

When they desired to change their positions in the streams they merely accentuated the movement given them by the water. Nobody knows just how nature adapted these early pioneers to their new environment and mode of life. We do know that at all times and in all places she has found a way to fit her creatures for the lives they lead. Perhaps æons of failure preceded the time when a body capable of the arduous activities of existence in running water was finally born. Along either side of such a body segmented muscles had to be developed, complicated muscles through which the

animal could send waves of contraction. The flabby invertebrate body had to be stiffened to support these muscles. R. S. Lull suggests that perhaps the first support was a membrane made rigid by water under compression. Later came an axial support of cartilage and finally a rod of little jointed bones to give strength with flexibility. Fins for balancing grew out of folds of skin on back and sides. In some way not explained by this theory the other attributes of a fish were eventually acquired.

Those invertebrates that had wandered into estuaries and sluggish streams during late Algonkian times found themselves in a predicament when the low lands were uplifted at the close of the era. Streams were everywhere quickened and weaklings were washed back to the sea. Undoubtedly many of those who tried to fit themselves to the new conditions failed. The coming of the fishes attests that some of them succeeded.

Many fishes returned to the sea after they had perfected their bodies in the rivers. Life was easier there. Some of them evolved a spindle-shaped body capable of rapid and easy movement through the water. The same body style was later adopted by certain seagoing reptiles and finally by such mammals as the dolphins. Such a body is the finest known adaptation to life in the water. When you see a school of dolphins gracefully skimming the water in the wake of your ship, you see perfection.

Many of the early fishes degenerated because the

influence of the sea is degrading. Under the sterner conditions of terrestrial waters they had quickened their minds and strengthened their bodies. In the sea, with those conditions removed, they merely yielded to a tendency inherent in all flesh. Despite the degeneration that fell upon some of the fishes who returned to the sea, the group as a whole gained easy mastery over the life about them. This was also true of those marine reptiles and mammals that were to come later, also the products of terrestrial conditions. It is significant, however, that none of these creatures gave rise to higher forms. With all their glory they were backsliders. Progress has always been born of the fiercer struggles on land.

When the fishes finally became abundant, the earth was ready for them. The invertebrates had reached and passed their peak. Their accomplishments were not inconsiderable. They had built bodies adequate to the element in which they lived. With limy skeletons they had fortified these bodies against the storms of their world. From them had come such highly organized animals as cephalopods and trilobites. But this is almost all that can be said for them. With the exception of the rise of insects during the late Palæozoic era, they have remained essentially where they were during the early Palæozoic era. Their descendants are in the seas today, differing widely in details of form and structure, but of no higher degree of excellence. They represent the conservative element in nature. The first fishes, on the other hand,

embodied the driving energy of life, the progressive principle in nature. They stood almost alone in a world of sluggards. But they were merely heralds of a greater day, and have long since sunk into oblivion. Before they died, however, they bequeathed to their descendants the priceless gift of backbone, without which there never could have been an amphibian, a reptile, a bird, a mammal, or a man.

VI

SPAWN OF NECESSITY

ONE day, forty years ago, a digger of fossils was breaking a rock near Canyon City, Colorado. The rock was sand from an Ordovician sea deposit, long since hardened and buckled into the air when the Rocky mountains were formed. Suddenly, when the rock parted under the blows of the hammer, a piece of shell was laid bare. Countless other shells had previously been dug from the cemented sediments of Ordovician seas, but never before a shell like this. For this was clearly the armour bone of a fish-like creature, proof of the existence of a backboned animal. Never before had rocks so old yielded any fossil higher in the scale of life than a crustacean. Redoubling his efforts, the searcher found many more fragments of the same sort, fragments that still stand as the oldest undoubted remains of vertebrate animals.

These and similar fossils discovered later in contemporaneous formations of Wyoming and South Dakota began the story of a queer group of fishes. Better remains of the same kind from later Silurian rocks continued the tale, which reached its climax and dénouement in specimens from the Devonian. It was the story of a failure, of a group of fish that swam in the wrong evolutionary direction into the never-never

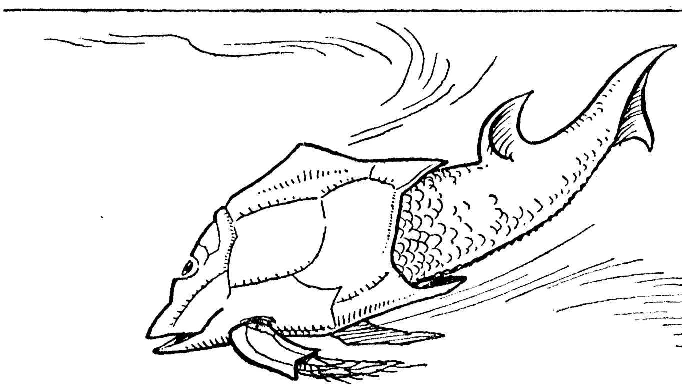
land of stagnation. Despite copious remains from many localities these oldest known vertebrates lie under a cloud. They have never revealed their relationship to the ancestors of fishes nor to their more successful brethren who somehow managed the long swim to the present.

Thus the ostracoderms, or "shell-skinned" fish, gain a little doubtful glory through isolation and mystery. The fashion of living inside a bony case, ever popular with invertebrate animals, was partially adopted by the ostracoderms. Their heads and chests were thus encased, but their hind parts protruded free and fish-like. In this bizarre combination of the old with a new idea is the suggestion of a compromise between the invertebrate and the vertebrate body. The suggestion, however, is deceptive. Enough is now known of these odd creatures to make it clear that they were much closer to the vertebrates than to the invertebrates, but still not in the main line of fish evolution. Most of them were sluggish grovellers in the mud who inherited their bodies not from backboneless ancestors but more probably from active armoured fish-like ancestors who lacked hard parts capable of preservation. Their armour came to the ostracoderms as armour has come to so many other creatures who have failed, as a last futile device to escape the inescapable.

Both the broken condition of the earliest ostracoderm remains, as well as the nature of the deposits from which they were unearthed, suggest that these

creatures lived in rivers. Nature, so often reactionary to the theories of men, sometimes withholds desired information, sometimes grants fragments of totally disharmonious information. In the ostracoderms she has done both. Science cannot weave these fishes into the main fabric of vertebrate evolution, yet because of their habitat and their antiquity, she must somehow

Ostracoderm (Pterychthis)



tie them to it. How the ostracoderms managed to degenerate in an environment that spurred their relatives to many noteworthy advances is just one of the disconcerting incompatibilities of the palæontological record.

Another lone wolf who cruised the seas of the Silurian and Devonian periods, oblivious to the direction of the main ichthyic advance, was the arthrodire of " jointed neck " fish. Like the ostracoderm, he was an evolutionary wanderer, and if survival is to be

taken as the criterion of excellence, a mistake. Yet in him was none of the obvious degeneration of the ostracoderm. On the contrary he was the most powerful animal of his day and in some regards the most interesting.

Nobody knows whence he came nor why he disappeared at the close of the Devonian period. Anatomists are still arguing whether he should be grouped with the ostracoderms, the sharks, or the lungfishes. In having a movable neck he could boast a character that no other fish of any age ever possessed. Before the dark waters of death swallowed him, he grew a massively armoured body over twenty feet long, and faced his fellows with jaws that bristled with terrible knives for lacerating flesh. Just when he had become, to all appearances, perfectly fitted to life in the sea, clearly the master of all he surveyed, he died. One of the earliest, he is still one of the best illustrations of the irony of fate.

The sharks that swam these early seas were prophets of the fishes of today. Most of them were primitive. Some carried many dagger-like spines on their backs and bellies ; others were as smooth as a kid glove, and except for their greater simplicity, not unlike modern sharks. With many other fin-driven marauders the sharks come out of an unknown past, flourished with abundance and variety in the later seas of the Palæozoic era, and weathered the hardships of time and tide to the present.

When their racial virility was still undrained, the

sharks give birth to the ganoid fishes of the flashy enamelled scales. The ganoids evolved into many varieties, and later gave rise to the true bony fishes of modern commerce and sport. The original stock did not fare so well. With extinction rapidly closing upon them they still cling to life in the garpikes and sturgeons of Eurasia and North America, and in two surviving primitive forms of Africa. But their days are numbered.

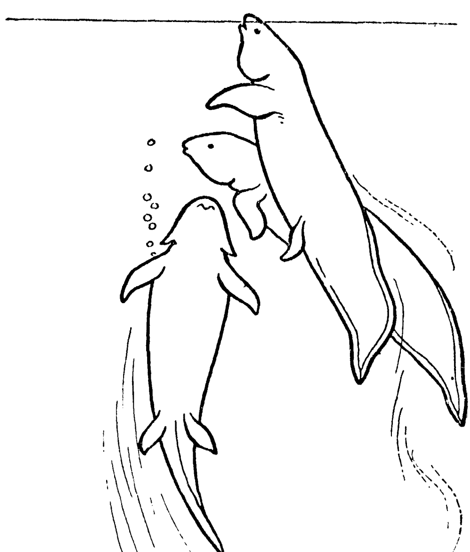
Most significant of all ancient fishes were the primitive lobe-finned ganoids and their near of kin, the lungfishes. Like the primitive sharks whence both were descended, their skeletons were largely of cartilage. The stiffened fins of the lobe-fins were highly suggestive of the limbs of the higher land-inhabiting vertebrates. The early lungfishes, like their modern successors, possessed swim bladders which could act crudely as lungs to take the place of gills when their pools dried up. In the bodies of these lowest of extinct fishes lay qualities which in the hands of others were to conquer a new world.

From the time when creatures first grew backbones, it was certain that the sea could not hold the more restless of her children. The land, so long the uncontested playground for wind and rain, was to become the chief theatre for the struggles of plants and animals. Those leaders who beat the first paths into the new country faced stern problems amid the dry rocks above the shorelines. Before they could travel

fast or far they were forced to invent new organs of respiration and locomotion.

Nobody knows the exact nature of those fishy explorers, other than that they must have started with the crude limbs of the lobe-finned ganoids and the

Lungfish breathing air



crude lungs of the lungfishes. Perhaps some day a digger of fossils will find the ancestors of these fishes, who will perhaps prove to be likewise the ancestors of the first four-footed land animals.

The living lungfishes of Australia, Africa, and South America re-enact some of the struggles of the earliest land vertebrates. When drought sucks dry their

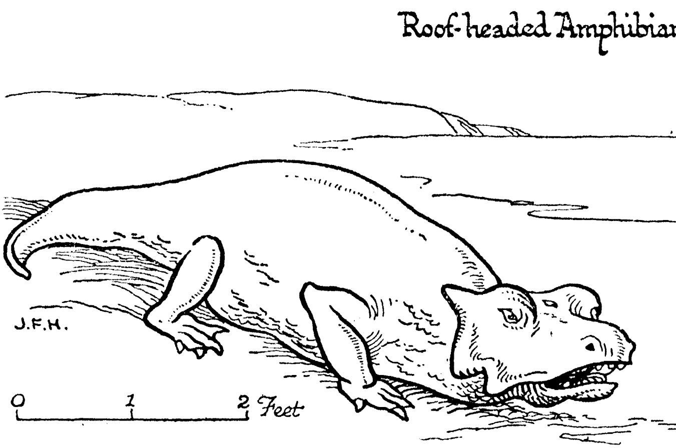
watery homes, they build cocoons of slime and mud, and gulp air into their primitive lungs through holes left for that purpose in their temporary houses. In this fashion they have been known to keep a spark of life burning for eight months without food. When the water returns to the bayous and swamps in which they live, they crawl out of their dissolving mud huts, breathe once more through gills, and in every way resume the normal life of a fish.

The ancestors of land vertebrates were perhaps equally well equipped with crude lungs, but also must have possessed fins that were strong enough to be used as limbs when the water receded from their mud flats. Instead of resigning themselves to passive resistance inside a cocoon, they paddled and pushed themselves over the shoals, searching for cleaner and deeper water where life would be easier. It was inevitable that some should have wandered towards the higher land. It would be too anthropomorphic to assume that the spirit of adventure drove them out of the water. Periodically the desert came and threatened death by suffocation. Surrounded by water too shallow to keep them afloat and stinking from the decay of their weaker companions, they had to bestir themselves or die. All improvements in living creatures have resulted from just such driving necessity. Forced to search for what had always been easily theirs before, creatures have stumbled unconsciously and unwilfully upon every noteworthy advantage they have ever gained.

Perhaps millions of years and millions of organisms were consumed before primitive lungs and limbs could be satisfactorily altered for life on land. How many years and how many fishes went into the manufacture of the first amphibian we can never know. We do know that perhaps during the late Silurian period the potential ingredients for an amphibian must have been present in the undiscovered ancestors of lobe-finned ganoids and lungfishes. We know that they lived under the stress of repeated aridity, a sufficient incentive for them to leave the water. We know that shortly after the close of the Devonian period, true land-dwelling backboned animals were alive. They may have existed before that time, and indeed it has been thought that one of them left a footprint in the mud of a Devonian swamp, a footprint that has defied all the terrors of subsequent earth movement, to lie in peace at last in the museum of Yale University. On close scrutiny, however, the rock in which the footprint is preserved is seen to be not a swamp but a typical marine deposit, containing the remains of marine shellfish that lived many miles from shore. No amphibian could have stuck his foot in such a place. Although revered at Yale and dignified by mention in a score of textbooks, the fossil is probably a deceit of the inorganic world, and its fame a splendid example of what Stefansson calls "the standardization of error."

As suggested by their name, amphibians are leaders of a double life. They lay their eggs in the water and

spend their youth there living the life of a fish. Most of them crawl out of the water when maturity falls upon them and acquire legs and lungs for life on land. From the beginning they have made a compromise between life in the water and life on land, never entirely giving themselves to either environment. Although they blazed the trail for others, they never quite attained to the excellence that might



have been theirs. After many millions of years they have not yet made up their minds. They still waver between two loves.

None of the splendour of the early amphibians is reflected in the insignificant newts, frogs, and salamanders who carry on today the tradition of the double life. Their fore-runners, the roof-headed amphibians, were perhaps the finest flower of evolution to bloom during all of the first three-quarters of geologic time. They overran the swamps and

forests of the late Palæozoic era, unquestioned lords of the new domain. Most of them resembled lizards superficially, but their heads were cased in solid bone, with openings only for nostrils and eyes. Unlike most other four-footed animals, the roof-headed amphibians looked out of three eyes. The third eye, like that of Polyphemus, lay in the middle of the forehead. Although it probably did not materially enhance the vision of its possessor, it was handed down to the present through unnumbered generations of different creatures, and has significantly enhanced the vision of evolutionists. It lingers complete in a modern lizard of New Zealand and vestiges of it are buried in the brains of all living backboned animals, including man.

Not only the head but the remainder of the body was protected more or less with armour plates and scales. Some of them grew so smug and fat that their bellies dragged painfully on the ground. Others were snake-like, active runners and swimmers. One looked like an overfed tadpole. Nearly all of them possessed flat broad heads and unbelievably wide mouths, with which, had the bones of their head allowed, they surely might have whispered into their own ears. Most of them were larger and more formidably armoured than the naked little creatures who survived them. Some were more than five feet long. But, as is so often the fate of magnificence, most of the roof-headed amphibians crawled off the scene as the light of the Mesozoic era began to dawn.

Before they passed, however, they left to posterity something more than their bones. Out of the struggle of the early amphibians to free themselves from the water, the reptiles were born. These creatures, represented today by lizards, snakes, turtles, alligators, and crocodiles, are still superficially more like the amphibians than like any other backboned animals. In the beginning they resembled the amphibians so closely that experts are sometimes at a loss to distinguish between them.

Most of the Palæozoic as well as most of the later amphibians showed unmistakably the mark of the fish. They were clothed in slimy skins which were healthy only when moist. Like fish, the females laid many small eggs in the water, which later were fertilized by the males. The eggs hatched into young who breathed through gills in a medium that would quickly have drowned their parents. To free themselves from the water the amphibians faced the problem of laying larger eggs which could hold a sufficient supply of food to nourish the young for a longer period before hatching. Only in this way might the water stage be eliminated, and the young begin to breathe the air at birth.

Those amphibians who gave rise to the reptiles solved this problem. Their eggs were not only larger, but they were surrounded by shells to protect them against drying out in the air over the land. For the same reason fertilization was effected within the moist bodies of the females, where the sperm cells

could live until their work was done. In practising internal fertilization the early reptiles established a habit which ever since has distinguished the higher from the lower backboned animals. In the first reptilian egg to weather the storms of a far-off Palæozoic land was the promise of a decisive victory over the new environment.

Once free from the water, the reptiles were able to explore the land at will. In time they developed certain anatomical peculiarities which easily distinguish all later reptiles from later amphibians. Even before the close of the Palæozoic era some of these differences began to show. Not a few of the early reptiles managed with four fingers on the hands instead of the five possessed by many amphibians. Their skulls were normally joined to their backbones by one bone beneath the spinal cord, rather than by two bones, one on either side of the spinal cord, as in typical amphibians. On the whole, however, their anatomy differed only slightly from that of contemporary amphibians. They exhibited few of the excellencies that were soon to make them the greatest animals on earth.

During the closing stages of the Palæozoic, amphibians and reptiles pursued their destinies side by side. Along the rivers and pools of southwestern United States they lived and died together. Most of the first reptiles lingered near the water. From the deposits of an extinct lake in Texas have been dug many specimens of many generations. Most of the skeletons

tell stories of fat and uninspired creatures, of some who retained the armoured skulls of the roof-headed amphibian, of others with long necks and tails for swimming. A few had claws for climbing trees, but they were exceptional—and unsuccessful.

The bodies of these creatures contained the promise of great happenings in the future. Glorious enough against the background of the past, they were without distinction against the future. Sharing with them the adventures of a new environment was another quite different order of living things. For the first and only time in the history of life, those usually undistinguished attendants of the march, the plants, pressed to the head of the procession. Long eclipsed by the superiority of animals, plants had finally come into their own. So luxurious was the vegetation of the late Palæozoic era that the little animals and their little activities were all but hidden from view.

VII

THE VEGETABLE VERSION OF PROGRESS

THE uniformity that bound all creatures under the pre-Cambrian sun slowly dissolved with the passage of time. Two different philosophies of living took form in the protoplasm. The one sought heaven through the bodies of plants, the other through the bodies of animals. Because plants have ever been held to a lower chemical level of existence than that on which animals have moved, the one gave birth to a tree, the other to a man.

Plants and animals early parted company over the matter of nutrition. Plants continued to eat the food that must have nourished all creatures in the beginning. Few of them have ever craved anything better than the gases and liquids abundantly offered by air, earth, and water. Sunlight working through green chlorophyll wrought these simple substances into the complicated starches, sugars, and other constituents of the plant body. Animals, on the other hand, early tired of an exclusively gaseous and liquid diet. From the bodies of each other, but ultimately from those of their vegetative neighbours, they poached the solids that alone could appease the new appetite. Animals have been stealing from plants ever since. If they had been honest with their associates they would never

have succeeded as they have. To the venerable institutions of murder and larceny, man himself owes his existence.

All the obvious differences between plants and animals grew out of this primary difference in diet. Different food required different organs for digestion and assimilation, different feeding habits. The complicated alimentary tract of some animals never developed among any plants because none of them ever needed it. Because the food of plants is almost everywhere available, most of them have clung to one spot. Because the solids so dear to the stomachs of animals are quickly consumed in any given place, most animals have become active prowlers. The food they eat makes chlorophyll and cellulose in the bodies of most plants whereas the food of animals turns to colourless flesh and bone. Because creatures ever mould their careers with their mouths, the passive and primitive feeding habits of plants have kept them sluggish and simple. The active and complex feeding habits of animals have rendered them more sensitive to stimulation, more elaborate in the architecture of their bodies.

In their own way the simple bacteria and algæ of the dawn seas groped toward higher things. At first these children of the water were utterly dependent on their parent. Water gave them the seed of life, nourished it to maturity, defended it against its strongest enemy, desiccation. Water buoyed up their spineless bodies. So long as these creatures lingered

in places where the water supply never failed them, they were safe and unprogressive. But among them were restless ones who followed the wanderlust to strange places. These learned to live not only in salt and fresh water but also in swamps, lakes, and tidal lagoons. There they heard the siren song of the land, and like animals they were compelled to answer it.

They who inhabited waters that suffered annual drought were faced by the same problems that faced the amphibians. They were forced to equip themselves with protective devices to stay suffocation under air, organs that would sustain them until the life-giving waters returned. Mosses and liverworts, which occupy a position among living plants similar to that of the amphibians among animals, are probably survivors from those primitive plants that not only fortified their bodies against periodic drought, but by so doing opened a path to the dry land.

The first steps toward the excellence that later reached its highest expression in the flowering plants of the land were the dying gestures of simple vegetable organisms while they slowly suffocated in the evaporating waters of early Palæozoic lakes or swamps. Their bodies, like those of all other simple organisms, were plastic. Those who survived succeeded in growing little fleshy projections with which they could pierce the damp soil and suck the last drops of the vanishing moisture. Above them were the scorching rays of the sun, the hot breath of the air. Many unfortunates wilted before a few were able to

build a cuticle to protect their delicate bodies from the shrivelling heat of the new environment. At the same time they stiffened themselves against complete collapse in a medium where everything must support its own weight. In similar fashion the rootlets were adapted to pick food as well as moisture from the soil, and other parts of the body were modified to breathe air instead of water. Primitive plants gained all these victories before they had grown enough woody tissue to enable them to leave a fossil record of their achievements.

Plants did not appear conspicuously in the geological record until the Devonian period. Perhaps the lands of the early Palæozoic were not entirely devoid of vegetation. Then the world was as friendly to life as now, and today plants live almost everywhere. Not all of them linger where life is easiest. They cling to the frozen tundras of the northland and defy death on waterless deserts. They brave the wind-combed crevices of Alpine summits and the wave-churned waters of the open sea. Even in the Stygian caverns of petroleum reservoirs they live, and in the intestines of men. Such adaptations were not gained in a day, nor were they probably the result of anything very new on the earth. There can be little doubt that long before plants grew skeletons tough enough to be preserved as fossils, they had adventured into every conceivable habitat.

The fossil vegetation preserved in Devonian rocks

at Rhynie, Scotland, contains many plants that were clearly transitional from the water to the land. They rose from creeping underground stems to a height of six or eight inches. A cuticle toughened their flat, narrow branches against the dry air, and primitive rootlets sucked nourishment from the soil. Toward the close of the Palæozoic era, many lands stood low and suffered frequent inwashings from the sea. Vast areas were alternately covered with marine water and later converted into brackish swamps by rivers carrying in fresh water and rock waste from the higher land. In these swamps primitive land plants reached their loftiest expression. Here countless generations lived and died and were later transformed into the world's most valuable coal.

Although the ferns and fern-like plants of these forests were primitive, they embodied many of the virtues that led to the later evolution of the plant kingdom. The ancestors of the ferns wandered away from the mosses and liverworts much as the reptiles parted company with the amphibians. Unlike the reptiles, the ferns have never become completely successful citizens of the land. But in any comparison of plants and animals, the former must droop a little before the latter. Plants are the weaker sisters of the organic family. Their radiance is that of moonlight: pale when the sun is shining.

The success of a man's life is not infrequently a measure of the success of his sexual adjustments. This is merely a survival of conditions that have obtained

ever since reproduction became entangled with the mechanism of sex. The general advancement of both plants and animals, if not the result of improvements in the sexual mechanism, has certainly been a concomitant phenomenon. Plants have ever been less fortunate in their sexual adjustments than animals and perhaps that is one reason why trees (despite the excellence of some) are inferior to men (despite the debasement of many).

Spectacular as were some of the plants of the late Palæozoic they were fundamentally simple and restricted. Their sexual lives chained them to the water. Most of them reproduced through spores rather than seeds. Spores, which can be seen today in little clusters on the under side of a fern frond, germinate only when they fall on wet ground. The plants that grow from fern spores do not look anything like ferns. They are but tiny flat blades scarcely more than a quarter inch long. Each blade grows sexual organs of reproduction which generate egg and sperm cells. When ripe the sperm cells utilize whatever moisture is available to swim to the eggs and fertilize them. Each fertilized egg grows into a spore-bearing fern and the process is repeated.

Thus all spore-bearing plants consist of two interdependent generations, the one sexual and the other non-sexual. In all of them the sexual stage is dependent upon water. Not until after the close of the Palæozoic era did most plants succeed in subordinating the sexual stage sufficiently to escape the need

of abundant water during reproduction. The magnificent giants of the coal forests were after all only halfway along the road from a seaweed to a shade tree.

For races as well as individuals, life consists of moments adrift in eternity. During the Pennsylvanian period in North America the ferns realized the greatest moment of their long lives. One family grew into trees that towered more than sixty feet into the air. Such giants were possible because their world was the best possible world for them. In the moist warmth of the swamplands, under climatic conditions that apparently varied little throughout the year, the ferns could grow during each day of their lives. None of them had the annual rings of trees that live where climate undergoes seasonal changes.

Their bodies were architecturally superior to the flabby edifices of their ancestors. The cells of the conspicuous spore-bearing generation had departed from the haphazard arrangement typical of the cells in the diminutive sexual generation. They had become elongated and joined to form pipes, which not only enabled food to pass more readily from roots to leaves, but materially strengthened the entire body. Although their wood was spongy and weak compared with the wood of modern trees, it was strong enough to support the weight of sixty-foot trees in forests sufficiently dense to reduce the most vicious wind to docility.

All the ferns of the Pennsylvanian forests were

not of Brobdingnagian proportions. Smaller ones crowded the feet of the larger, and found haven in the crevices of their trunks. The majority of the plants of this period bore fern-like foliage, and until quite recently they were all thought to be true ferns. It is now known that some of them produced seeds rather than spores, although in all other regards they resembled ferns. Perhaps these " seed ferns " were the link between primitive and modern plants. Because their fossil remains are so difficult to distinguish from the fossil remains of true ferns, science has not yet discovered their exact status.

The ferns in all their glory lay under the shadow of of the gargantuan club mosses. Today the thinning remnants of these remarkable plants are diminutive degenerates nearly lost amid the higher vegetation of modern swamps and forests. Throughout the late Palæozoic, however, they were not excelled in variety and magnificence. The scale tree, *Lepidodendron*, was an arrow whose shaft rose straight and slender for more than one hundred feet. On top was a crown of many branches, here and there tipped with the club-like cones that housed the spore bodies. Growing directly from the trunk were many slender grasslike leaves arranged in spirals. Characteristic diamond-shaped scars remained on the bark when the leaves were shed. Under each leaf were two rows of spores, through which the tree sucked carbon dioxide out of the air. Underground long forking stems burrowed horizontally and from them rootlets

stretched in every direction in search of food and water.

Not very different from the scale tree was *Sigillaria*, the seal tree. Its leaves, in some species fully three feet long, clung to the trunk in vertical rather than in spiral rows. Its head resembled a giant pineapple. Many were squat but some were six feet thick at the ground and one hundred feet tall. Several hundred different kinds of extinct club mosses are already known. Their compressed remains constitute the bulk of some of the most valuable coal deposits. After many millions of years, they radiate the warmth of a sky long since grown frigid, and by entering the flesh of man they fill also a small place in his memory. Extinction has dealt less sternly with them than with most others.

Almost equally commanding were the giant horse-tails whose slender jointed spikes rose from sixty to ninety feet above the ground. At each joint a whorl of leaves surrounded the trunk like a collar. They flourished in splendour throughout the late Palæozoic, but gradually grew smaller until today they share with the ferns and the club mosses the ignominy of degenerate survival.

Botanically the finest tree in any Palæozoic forest was *Cordaites*, more than one hundred feet tall and crowned with a flaring head-dress of large sword-shaped leaves. Its wood was not unlike the wood of higher trees, and it reproduced by seeds in the modern fashion. Although it probably helped bridge the gap

between the ferns and the evergreens, it disappeared soon after the close of the Palæozoic era.

For many millions of years over many thousands of square miles such trees as these possessed the land. Throughout their vast domain scarcely a flower showed against the monotonous sea of green. Only the gaiety of the wind-tossed yellow and brown spore dust at times dispelled the sombre gloom. No birds warbled in the dark depths. Not one insect could utter a chirping noise. Only the lugubrious love croaks of amphibian or reptile, the crackle of falling branches, broke the long silence. Nature had not yet learned to laugh.

It was a day of prodigious enterprise, birthday of the familiar bigger if not better philosophy. Not only the plants but many of the insects were giants. These arose, perhaps from trilobite ancestry, with small heads, six legs, wings, and ten abdominal segments equipped for breathing air. From this primitive stock came many others, ancestors of dragon-flies, May flies, grasshoppers, crickets, cockroaches, lice, and beetles. All were large. One Pennsylvanian dragon-fly had a wingspread of two and a half feet. Cockroach kings fully four inches long put to shame the modern denizens of dirty kitchens. Although these creatures lived in a world of succulent vegetation they were all meat eaters. They lived on each other and on the lesser invertebrates who had also tried the land. They in turn made food for bloodthirsty scorpions, spiders, and thousand legs,

who lived in the ground or in logs rotting on the forest floor.

Usually in the history of life those forms that bridge the gap between lower and higher creatures are either obscure or unknown. The late Palæozoic forests were the outstanding exception to this rule. Both their plants and their animals were almost universally transitional in type. Their glorification presented one of the weirdest assemblages of living things ever recorded. Today almost nothing is left of them but the record.

Had they not lived at a time when great changes were brewing, many of them might have walked with some dignity to the present. Unfortunately earthly paradises are only temporary heavens. At the close of the Palæozoic, the conditions so friendly to life were wiped out of existence. With them went many organisms and many others were sadly reduced in size and number. Before we can understand such vagaries in the fortunes of living creatures, we must go deep into the interior of the earth and interview the lords of the underworld who, these many æons, have shaped the fate of all that cling to the surface.

VIII

AN ANATOMY OF HELL

DANTE roamed with safety through the Inferno of 1300. If that benign gentleman could visit the Inferno of modern science, he would do so only to emerge as a puff of gas. To the theologian hell as a place is becoming hell as a condition. But while religion turns its eyes to heaven, science looks below. Ancient theological concern for the kingdom of Lucifer has changed into modern scientific interest in the interior of the earth.

The subterranean has always whetted the imagination of man. Some of the oldest ideas of a burning in the bowels of the earth grew in the minds of Mediterranean philosophers. There is a geographical reason. The Mediterranean basin is a weak zone in the crust of the earth, where rocks crack and volcanoes belch smoke and lava. Many early thinkers linked earthquakes and volcanoes with an abyss of unthinkable hotness, a fit place for banished souls. A sunburned philosopher near erupting Etna could easily imagine hell.

Before Aristotle gave finality to early thought on nature, man had pictured the land of abandoned hope. Certain ideas dominated. Fire, wind, and chaos were the ingredients in the Stygian pudding. Aristotle

conceived a hollow earth filled with the fires of exploding air. Lucretius saw the interior as a dark replica of the surface, with rivers of ink, gorges, cliffs, caverns, and a snarling wind that struck fire from the rocks. Seneca thought volcanoes were born in the escape of captive winds igniting coal and sulphur as they whistled through the rocks. Æolus, who lived under the volcanic Æolian Isles, unleashed the winds that fanned the fires of hell.

The internal depths were sufficiently terrible to fit the needs of the old theology. The hell idea grew until the land of Charon was known and feared by every peasant in Europe. This theological realm slowly cooled. The wails of the wicked no longer gripe the entrails of the world. The twentieth century has little interest in the Inferno of mythology. Yet the region hitherto reserved for the damned draws the thought of the modern scientist. Some of his conclusions about the interior of the earth are interesting.

The geologist has not found "easy the descent to Avernus." After groping in the dark for several decades, he only now begins to see the light. A germ on an eggshell cannot know the inner workings of eggs. Man is a germ on the shell of the earth, but a germ with reason and imagination. With these he has dug a tunnel toward the buried truth.

An invisible foe is hard to overcome. No problem has been more baffling than the problem of the hidden heart of Earth. Speculations bristle like bayonets at

the front of an advancing science. In the eighteenth century the illustrious French mathematician, Laplace, destroyed the ancient conception and filled the wind-swept hollows of earth with liquid rock. He thought the earth a liquid sphere with a thin crust. Some scientists accept this postulate in a modified form today. Most others have come to think of the earth as essentially solid to the core.

Men have bored holes in the crust of the earth, mere pin pricks in comparison with the radius of the planet, but deep enough to reveal a story. Every hole grows warmer toward the bottom on the average of one degree Fahrenheit in sixty feet.* Nobody knows that this rate continues below the deepest boring, one mile and a half under the surface. Volcanoes hotly argue that it does. If the rate persists, temperatures at a relatively shallow depth are high enough to melt any substance known to science. Granted this increase in temperature and the absence of modifying conditions, the rocks of the crust must grade into a hot incandescent liquid.

Some thinkers believe in the existence of a liquid substratum engirdling the earth rind within fifty miles of the surface. Striking facts support this concept. The continents are largely composed of light rock like granite. The ocean beds and their volcanic islands are made of somewhat heavier rock called basalt. The greatest lava flows of geological history brought underworld basalt through fissures to the surface.

*Some scientists say ninety feet.

Such facts suggest that both oceans and continents rest upon a universal layer of basalt. The continents stand high because they are made of lighter materials, separated by gravity in the original distribution of things. They float like icebergs in a sea of basalt.

An earth with such a foundation might easily be weak. That it is weak the geologist has found abundant evidence. He has read the story of a long life of suffering in the face of the earth. He has studied her wrinkles in mountain ranges. He has seen her scars. Blocks of her crust have foundered along mighty rifts. The Red Sea now occupies such a depression. The voyager, standing on a high peak in Glacier National Park, sees stupendous beauty and serenity. Yet beauty and serenity have been born of pain and travail. The mountains were once mud on the bottom of an inland sea. They were later hardened, uplifted, sculptured by water and ice, and thrust into their present position, thrust westward seven miles or more. The poorly healed scar is clear to those who can see. The earth has suffered.

Despite the weakness of the crust, the body of the earth is strong, so strong that many scientists cannot accept the belief in a liquid substratum. This internal resistance to deformation is probably due to the strengthening of materials within the earth by the tremendous pressures of the overlying crust. Experiment has proved that most rocks cannot be changed

from solid to liquid unless an increase in volume is permitted. If pressure is great enough to prevent expansion, a rock remains solid in spite of its temperature. The exact nature of a substance so hot that it would immediately turn to a liquid at the surface of the earth, but which remains solid under the pressures of the deep interior, is one of the unsolved riddles of earth physics. Such a substance may be crystalline like a solid rock or amorphous like a liquid. Nobody knows. It is certainly elastic and rigid under sudden stress, but it may also be plastic under prolonged stress. Expert opinion declares that the earth as a whole is in a state of elastic rigidity.

Some believe in a substratum that alternates rhythmically from liquid to solid, under the control of radioactive minerals, which are the furnaces of the underworld. All such substances can be traced to two parent elements, thorium and uranium. These are the heaviest known elements in nature and the least stable. They are stirred constantly by a slow turmoil of the atoms which changes them from one form to another, until they finally assume the properties of lead. During their decay, rays are shot out with the speed of light and heat is generated. These elements are unaffected by heat and pressure; in fact, nothing has been found that can alter the rate or the character of their transformation. They stand alone in all nature, independent of outside influences. Widely scattered through the rocks, they constitute an almost everlasting source of heat. Our modern hell is paved,

not with good intentions, but with radioactive minerals.

The Irish physicist, Joly, has postulated a solid basaltic substratum that is periodically changed to liquid by the slowly accumulated radioactive heat, held captive by the low conductivity of solid rock. The previously solid basalt becomes liquid when sufficient heat is generated, expands, and uplifts the ocean basins so that the seas invade the lands. Heat is then rapidly lost by thermal convection in the liquid substratum and the basalt again congeals. The ocean basins sink with the contraction of the cooling basalt. Seas withdraw from the lands, continents are squeezed between the foundering ocean troughs, mountains rise; a new cycle of heat accumulation begins. This theory affords an ingenious explanation for the cyclical nature of the chief events in earth history. But it is only a theory. No one can know exactly how much liquid rock existed in the earth of past æons. No one can be sure of the amount present today. Science is sure that, liquid or solid, the earth at the present time is superlatively rigid. It acts like a solid body, yielding to deformation with the willingness of steel.

Every schoolboy knows the story of the egg of Columbus. Not many have heard about the eggs of Lord Kelvin. Kelvin was half a century in advance of his colleagues when he contended that a fluid earth could not spin on its axis. He demonstrated with a hard-boiled egg and a raw egg. The boiled egg, rigid to the core, could be made to spin with ease,

but the raw egg with its liquid interior refused to spin.

Kelvin further pointed out that if the earth were liquid, tides generated in the oceans by sun and moon would likewise operate in the body of the planet. The crust of the earth would suffer upheavals and depressions with the revolution of sun and moon. The earth is not the toy of the tides. But Michelson and Gale, in one of the most brilliant experiments in modern science, have recently proved the existence of feeble tides in the crust of the earth. They entrenched five hundred feet of pipe six feet in the ground, filled it with water and sealed both ends. They measured the water level in the pipe by minutely exact methods. Tidal stresses in the crust of the earth slightly tilted the pipe and caused variations in the water level. Computations on the degree of tilting showed that the earth yields a little, but only a little to the pull of sun and moon. The tides in the body of the earth were found to be about three-tenths of what they would be if the earth were liquid.

The earth is no fairy sylph. She tips the scales with a weight more than five times that of water. Since her rocky epidermis is not quite three times as heavy as water, her vitals must be several times heavier. The difference in the weight of the inner and outer parts of the earth's anatomy is explained through the fact that all known substances can be compressed. With compression they grow denser—that is, heavier. Even the lighter rocks of the crust are heavy enough

to crush the inner core and raise its density. The inner core is thought to be at least as heavy as iron.

The earth is crudely layered. The surface granitic rocks fuse below into the heavier basaltic substratum, which in turn passes into still heavier material. The core is thought to be made of iron alloyed with nickel, suffering terrific pressures that increase its density. Most of the meteorites that have fallen upon the earth are iron: stray blocks, perhaps, of the building stuff of other worlds.

The layers of modern Inferno are not as sharply defined as the ethical circles of Dante. One layer merges into another as the density grows gradually with depth. Three zones have been described: the outer stony shell containing the crust and the substratum, an intermediate zone of mixed stone and iron, and the predominantly iron core. These zones fit the known facts of cosmogony, astronomy, earth physics, and geology. Nobody has seen them. They are quite inferential. They are guesses, but guesses born of study.

An earth thus stratified may demand a certain amount of fluidity, at least during birth and adolescence. Whatever may have been true in the past, pressure clearly has the upper hand in its struggle with temperature at the present. When the crust cracks and pressure is locally released, underworld materials rush to the surface as lava. Ordinarily they are held rigidly to their places below. Paraffin, which flows easily when slightly heated under pressure of one

atmosphere, under thirty thousand atmospheres can punch holes in steel. Earth materials are thus compressed and stiffened. There are no waste spaces in modern hell.

The earth is old, and quakes constantly. Volcanic explosions sometimes suddenly shift the position of rocks. A local earthquake results. Great quakes are due to major collapse in the architecture of a crust that is overstrained. The elastic strength of the interior prevents breakdown until stresses have accumulated to the last straw. The back of the earth then breaks, masses of surface rock slip along great rifts, a nervous tremor passes over the face of the earth.

Earthquake waves have destroyed large cities and as death dealers they have always ranked high. But through them science peers to new knowledge. When Poseidon shakes his finger, waves quiver through the rocks in all directions from the point of origin. They travel curved paths through the body of the earth, vibrating as they go, both in the direction of their route and transverse to it. Earthquake speedometers, called seismographs, measure the speed at which the shock is spread. This speed increases as the tremor penetrates the interior, proving that elasticity and rigidity increase with depth. Transverse vibrations cannot pass through anything but a rigid substance. A bell of putty would not ring. The earth is like a bell of steel.

Experiment sustains observation to prove that the earth gains strength with depth. A rock that can be

crushed with a hammer under atmospheric pressure must become adamant in the interior of the earth under pressure of many thousands of tons. All rocks gain strength when compressed.

The crust itself has elements of strength. Mont Blanc rises more than 12,000 feet above her base and does not collapse. It is true that the crust has often cracked, buckled, and wrinkled under strong one-sided pressure. Yet such disturbances have come only after long periods of comparative quiet. Whole mountain systems have been stable for long periods. The earth stores its stresses until they have grown beyond the elastic endurance of steel.

Thus have we travelled far from early beliefs about the earth. Out of the mould of superstition has grown an intelligent conception of the inside of our planet. But unsolved problems lurk in the inner darkness. The rôle of fluidity in the past is still uncertainly known. The rôle of fluidity today is debated. But the rigidity of the earth is proved beyond refutation, and, for that reason, modern science is moving toward belief in a solid globe.

All this has no effect upon the cost of living. Yet the desire to understand persists. The scientist, with infinite patience, has gained his little victories: with long days and lonely nights at the crater of some reeking volcano, with heartbreaking months in the laboratory when nature refuses to yield. Slowly he is solving the riddle of the depths. In his own way he follows in the footsteps of Dante, who also sought the meaning of things.

IX

WHEN THE BACK OF THE CAMEL BROKE

AT the beginning of the Palæozoic era an architectural pattern was established for the continent of North America. To the east and west of the present margins, in the Atlantic and Pacific oceans, respectively, were the unstable highlands of Appalachia and Cascadia, long since worn by the elements into oblivion. At their inner bases, where now stand the Appalachian and Rocky mountains, lay great troughs open to the outer oceans. Despite frequent local warpings of the crust, North America did not deviate far from this pattern throughout the era. Streams from the flanking highlands slowly gnawed them down, and dropped the refuse into the longitudinal troughs. Ocean water continuously possessed the troughs and frequently overflowed into the great interior basin. But the face of the earth was essentially at peace.

Underneath, however, the planet was storing terrific stresses. At least three times before the close of the Palæozoic these stresses were released locally and the surface was buckled into small mountain ranges. But this was only the forecast of a direr future. The great crash came at the end of the era. More than thirty thousand feet of mud and sand had been piled into the Appalachian basin. The earth, no longer able

to resist the stresses within her, gave way in her weakest zones. From Newfoundland to Alabama the surface bulged in monster cracks and wrinkles. Mountains were thrown five miles into the air.

To the west the Rocky mountains arched their backbone from the sea, and imprisoned an arm of the ocean on the east. Because the arrival of moisture from the west was blocked, the great bay was eventually sucked dry. The salt left behind lay like a blanket of snow to tantalize the parched lands. Volcanoes belched gas, dust, and lava from California to Alaska. Everywhere the great seas and marshes were driven off the land. In the south-west, embayments from the Gulf of Mexico lingered on the continent after all others had fled before the conquering uplift and aridity. But they too eventually succumbed. By the close of the era, North America was fully as high as and considerably drier than it is today.

In many other places where the surface had been weakened through the accumulation of rock waste, mountains were born. Europe, Africa, Asia, Australia, and South America were all in the throes of the universal turmoil. Deformation was not contemporaneous throughout the world although most of it occurred during the middle of the Pennsylvanian period. By the end of the following Permian—final period of the Palæozoic era—most lands stood high and suffered erosion. Then at last the greatest cataclysm in more than one hundred million years had abated, but its effects can still be seen in lands and creatures today.

The immediate effect was the most profound alteration of climate the earth has ever suffered. North America was not the only land to fall under the domination of the desert. In Europe the Armorican mountains, rising along a belt that stretched from Ireland, through England, France, and into Spain, slowly built a barricade against moisture-freighted winds from the Atlantic ocean. Coal swamps evaporated and in their place came the desolation of red desert plains and salt lakes. On the east a tongue of the Mediterranean licked for a time the flanks of the newborn Ural range, only to be driven back by the desert.

The building of mountains always disturbs the circulation of atmospheric and oceanic currents. Spectacular as were the effects of such derangement in the northern hemisphere, they were pallid when compared with the widespread glaciation that came to the lands of the southern hemisphere during the Pennsylvanian and Permian periods. Gigantic ice caps, comparable in size with the frozen cross on the back of modern Antarctica, settled over equatorial lands. Africa, India, South America, and Australia, where now the tropical jungle thrives, were then buried under several thousand feet of snow and ice. Rising in the highlands over the equator, the greatest glaciers in history flowed into torrid lowlands and actually entered the tropical seas before melting. In Australia the ice formed and melted repeatedly. Between the glacial climates were climates so mild that warm water

animals could live in the oceans and coal plants on the lands. Here at the close of the Palæozoic era was the most remarkable succession of climates ever recorded.

There is yet no adequate explanation of these glaciers, or for that matter, of any glaciers. The causes are interwoven with atmospheric and oceanic conditions that have, in this case, long since vanished. The effects, however, have been preserved. When the ice sheets melted away, many thousand square miles of lowlands were buried under several hundred feet of rock waste worn by the glaciers from the uplands. Seas were cooled by the inflow of ice water, and they in turn chilled the overlying air. Throughout the southern hemisphere the luxuriant coal forests dwindled in the cold. Smaller and tougher plants took their place and followed the icy currents into Europe and Asia.

The most significant changes in the lives of plants and animals were due to no single factor. Elevation of mountains, draining of inland seas, derangement of air and ocean currents, glaciation, and aridity combined to harass the life of every sea and land. Death stalked everywhere. So widespread was the destruction of life that early investigators thought the slate had been wiped clean at the close of the Palæozoic era, and that a new creation had later been established by a remorseful divinity. We now know that although thousands of plant and animal species perished, a few were able to

weather the crisis. They closed the ranks and marched on.

What glaciation did to the plants of the southern hemisphere, aridity did to those of the northern. The ferns, hardiest and most abundant plants of the time, were reduced in size, variety, and number. Most of the club mosses were killed, but a few lived on, stunted almost beyond recognition. Horsetails weathered the storms of the age but emerged quite shorn of glory. Not one survived as a tree. Everywhere the giant land plants were slain or transformed into dwarfs.

Nature, fundamentally cruel at heart, yields not infrequently to a sort of whimsical benevolence. She inflicts the pain of childbirth but grants the pleasures of childhood. She makes death horrible, but allows that by contrast life shall appear beautiful. She hurls catastrophe at the heads of her children with apparent glee, but permits that out of misfortune some good shall grow. So it was that in wrecking the most splendid forests the earth has ever seen, she spared the tiny seeds that held the promise of a new day.

Although she drove the seed-bearing *Cordaites* to the verge of extinction, she allowed certain obscure descendants to live. From them sprang the hard evergreen trees that dominated the plant life of the following era. Even before the end of Permian time, primitive conifers, remote ancestors of yew and sequoia, raised their heads amid a sandy gulf of desolation. They learned to live on deserts strewn with the dead bodies of their ancestors. When through the per-

fection of their seeds they abolished the need for water during the period of fertilization, they insured the future of the entire plant kingdom.

Accompanying them were the primitive ginkgoes with their small lobate leaves and plumlike seeds. In their swimming sperm cells they were the last of the higher plants to retain a vestige of the amphibious origin of all land plants. Today the ginkgoes have sunk from the splendour they rose to receive during the middle of the Mesozoic era, and are kept alive chiefly by Buddhists who consider them sacred. Although decay has almost won its battle with them today, it cannot remove the memory of a time when they joined with the ancestral cycads and conifers to carry the banner of a cause that would have been lost without them.

Backboned animals of the land suffered few of the hardships that fell upon their vegetable neighbours. With legs and lungs they were able to find oases where the pastures still were green and the air salubrious. The amphibians continued to live in abundance long after the opening of the Mesozoic era. The reptiles, only stimulated by the vicissitudes that carried death to weaker ones, rose to the mastery of the world.

Their cousins in the sea were not so fortunate. Tragedy rode on every wave. Only a few of the invertebrate species alive in the preceding period survived the Permian. Many of them had attained the meagre promise of their destiny and were prepared for

death by inscrutable forces within their own bodies. Others might have continued to live had not the whole world turned against them. An ironic fact that shows its ugly face in more than one phase of existence is that the greatest obstacles are often placed in the way of those who are least capable of surmounting them.

During the long periods of the Palæozoic era, shifting shallow seas crept back and forth over all continents. In them countless varieties of simple marine organisms found as much security as the impersonal forces of nature ever grant the children of flesh. They multiplied in species and individuals, and swarmed to the ends of the earth. When the seas were driven off the lands by the world-wide elevation of continents at the close of the era, their denizens were crowded together along the margins of the land masses. On one side was a lightless and foodless abyss; on the other, an impenetrable wall. They could do nothing but linger along the strand lines in an attempt to cheat the death that was pursuing them.

But death, alas, is not to be cheated. Many more creatures were crowded into a narrow belt of ocean water than the region could support. Ocean currents had been deranged by the turmoil on earth and air, and much of the plant food had disappeared. Thus herded together in a strange environment with far from sufficient food for all, the benighted company succumbed to a cannibalistic civil war. The strong devoured the weak. Those whose racial vitality had been diluted during the preceding æons of comparative

ease were the first to disappear. Many stronger ones followed because they were not quite strong enough to win with a pack that was stacked against them. So widespread was the destruction that fewer creatures were alive at the close of the Palæozoic era than at its beginning.

Many great groups of animals were completely erased. At one time the graptolites (so called because their fossil remains look like pencil marks on stone) swarmed in all the waters of the world. These simple relatives of coral and jellyfish passed without a survivor. Throughout most of the Palæozoic, that large group of spiny animals represented today by starfish and sea urchin, contained many types that lived anchored to the sea floor. Most of these sedentary ones perished. The last trilobite sank into the mud, and with him fell the last of the mighty sea scorpions.

The lamp shells, most abundant animals of the era, were reduced to insignificance. Three large subdivisions were nearly obliterated. The few survivors were made to limp painfully through the rest of their days. Corals were profoundly changed. The bryozoans or moss animals, for millions of years during the early Palæozoic the chief reef-building animals, were reduced to the edge of nonentity. The nautiloid cephalopods, once masters of the sea, escaped extinction by a margin thin enough to be miraculous.

It was the ringing down of the curtain for backboneless animals. A few found refuge and nourished the flickering spark of existence until better days returned.

But never after the Palæozoic era did they recover from their losses. Their misfortunes were not entirely the result of an unfriendly world. The star of their lives had already set and they were ready to die. The hope of the flesh was destined to climb upward through the bodies of quite different creatures. Out of adversity, qualities were born that made certain the success of backbone, qualities that empowered the reptiles for the conquest of land, sky, and water throughout the world. Out of adversity sprang the germs of a bird and a mammal. When the clouds of revolution at last were scattered, the light that was humanity shone clear though distant in the sky.

PART II

X

SAGA OF THE DINOSAURS

THE Mesozoic or medieval era in geological history saw the spasms of unrest slowly subside and comparative tranquillity creep into the features of earth. The smoothing hand of erosion stroked the ruffled surface. After the birth of the Appalachian mountains the lands to the east sagged along great cracks, in the relaxation that always follows turmoil. Long narrow basins paralleled the mountains from Nova Scotia to North Carolina. Here the rivers dumped their freight of coarse sediments riven from the highlands on the east and west. Rock débris accumulated on the basin floors to a thickness of several thousand feet. From time to time hot liquid rose from the still troubled interior and spread destruction over portions of the surface.

A hot sun beat upon a dry and sombre land. Now and then the bursting of a rain-soaked thunderhead freshened the desert wastes. Little lakes were born but they quickly vanished from an unfriendly world. Their ghosts, the salt and gypsum dropped from their evaporating bodies, lingered over the land. A few survivors from the vegetable lords of the past struggled for life on the red sands. Their heyday was over. The animals they had eclipsed were destined to return

to glory. Under a sun that shrivelled the bodies and the hopes of all other creatures, on a land as barren as the despair it bred, the reptiles began a career more brilliant than that of any animal before or since.

Although the path they travelled out of the past is lost in the turbidity of the Appalachian revolution, there is some reason for believing that it originated on the wasteland of a Permian desert. The squat four-footed habitués of late Palæozoic lands are the probable ancestors of the reptilian order that came into supreme power during the Mesozoic era. Those simple creatures held in their very simplicity the promise of offspring who could learn to live the hard life of the desert. Free from specialized bodies that would have chained them to one environment and to one way of existence, they were ready for anything. Hardships sterilize the weak but vitalize the strong. Because many of the early reptiles had the strength and adaptability of racial youth, they found food in the vicissitudes that poisoned so many of their contemporaries.

The ancestors of the Mesozoic reptiles originally lived in the warm waters of sub-tropical bayous. They were temperamentally and physically much like the crocodiles of today. When their friendly slime became dust they struggled in all directions in search of a new Paradise. It was a long trek from one oasis to another. Those who could not travel fast died of thirst and starvation. Many others, prodded on by the death at their heels, rose off their bellies and ran

like kangaroos. During the long æons when the desert breathed its hot breath on the land, reptiles were urged first into quickened bodily movements, then into many channels of adaptation never before open to land animals.

Out of such a past and under such an environment the dinosaurs eventually arose to fill the Mesozoic earth nearly as completely as mammals fill the earth today. They were the most conspicuous land animals, not only in the United States but also in Canada, Brazil, Patagonia, England, Belgium, France, Portugal, Germany, Africa, India, and Australia. Some geologists believe that a great continent once spanned what is now the north Atlantic basin, forming a bridge of land from Europe to the United States. They believe the dinosaurs to have originated somewhere on this lost land mass and from there to have radiated into almost every corner of the world.

These reptiles ranged from the size of a chicken to hulks more than eighty feet long and weighing more than thirty tons. Some combined the weight of an elephant with the blood lust of a weasel, and truly deserved the name of dinosaur, "the terrible lizard." Others were as vegetative and vegetarian as cows. Very soon in their evolution the dinosaurs moved from the ancestral stock along two distinct courses of development. There came two races, the one predominantly flesh-eating and with the hips of crocodiles, the other plant-feeding and with the hips of birds. Throughout their long history the dinosaurs maintained this basic

cleavage, although as with men, the adventurous frequently crossed the racial boundaries.

Where now the Connecticut river makes its way to the sea, at the end of the Triassic, first period of the Mesozoic era, both branches of the new dynasty had left innumerable footprints and a few bones on the desert sands. The flesh-eaters were small and agile, with the rudiments of many traits that distinguished their more impressive relatives of later days. A typical skeleton was four feet long—lizard-like, with well-developed hind limbs for running; degenerate dangling fore limbs for picking the bones of victims; a long tail to give counterpoise to the uplifted body; clawed fingers and toes; sharp, spine-like teeth. Judging from the abundant footprints of smaller contemporaries, this creature and his kind led an easy and toothsome existence. Perhaps that is why they never fully realized their latent powers. Their chief claim to fame is that later in Germany they gave birth to *Compognathus*, no larger than a rabbit, the tiniest dinosaur ever discovered.

Farther along the road to power was *Anchisaurus*, also a resident of the Triassic valleys of the Appalachian piedmont. The best specimens range from five to ten feet in length. The bones were strong but hollow, the feet and hands large and clawed effectively for a bloody business; the teeth, although partly rudimentary, were fashioned for murder. These animals were clearly transitional to the monsters that soon followed.

climax of a sanguinary race. He was death in a living body, the largest and most horrible beast of prey the earth has ever seen. Forty-seven feet of powerful flesh had been built into a body heavier than that of the largest elephant. Standing on massive hind limbs that supported his entire weight, he towered twenty feet above the ground. His head was more than four feet long, three feet deep, and nearly three feet wide. His jaws were set with daggers three to six inches long, and on his toes were claws as long as a man's hand.

It is not likely that in this massive hulk much of the ancestral agility had survived. In all his power, *Tyrannosaurus* no doubt paid homage to the laws of mechanics. These laws have never allowed the sprightliness of a grasshopper to enter the body of a colossus. Of his total tonnage, only one pound was allotted to the brain that guided him through life. His movements must have been not only slow and deliberate, but quite automatic and entirely lacking in quick adjustment to new conditions. Today he would be an easy victim for the more intelligent mammals. But his was an age of glorified dullness. No reptile alive at that time could have known much more than to eat, to reproduce, and to run from danger. For more than one hundred million years, muscle was the measure of success, and by that measure *Tyrannosaurus* was easily king.

While most of the dinosaurs with the hips of crocodiles were following the road that led to

Tyrannosaurus, others came down on all fours after the fashion of their ancestors and took to the more peaceful life of the vegetarian. They wallowed in the water and ate the aquatic plants of the swamplands, until gaining in weight and stature, some could scarcely drag their bodies to the dry land. They gave to the world the largest land animals that ever lived.

Brontosaurus, "the thunder lizard," nearly seventy feet long and weighing nearly forty tons, looked like an elephant with the neck and tail of a gigantic snake. His legs were massive columns weakly jointed after the fashion approved for water-dwelling animals. On land he could never be sure that gravity would not pull him to the ground and hold him prisoner. Only in the buoyant embrace of water was he happy. There his skeleton was remarkably efficient. The heavy pillars of his legs held him to a firm footing while he waded into deeper pools. His backbone was light and strong, his neck flexible. Half submerged he leisurely rooted the muck from dawn to dusk. His teeth had lost some of their sharpness, his claws their power to grasp, but he needed no longer the ancestral weapons. No enemy could follow him into the marshes, and the water plants on which he preyed faced death with the admirable indifference so characteristic of the vegetable world.

Diplodocus, a near relative, was longer but more slender. Sixty-five of his total eighty-seven feet were tapered fore and aft into neck and tail. An imperfection in a single vertebra or muscle of his back would

have caused several yards of his person to sag into the mud. No bridge builder has ever met the problems of stress and strain more effectively than nature did when she built this creature.

Gigantosaurus, who lived in East Africa during the Lower Cretaceous period, was the largest of all dinosaurs. He combined the massiveness of *Brontosaurus* and the length of *Diplodocus*. Unlike the others, his fore limbs were heavier and longer than his hind limbs. He could wade into very deep water and still have several feet of an almost unbelievably long neck for the endless quest after food. Calmly he munched his dinner, while on the bank disgruntled carnivores saw theirs just out of reach.

Not one of these ponderous animals had any effective means of protection other than the seclusion of their habitat. A few had long slender tails which may possibly have been used to whip away enemies. Along coastal marshes and bayous not unlike the everglades of Florida, they kept the comparatively noiseless tenor of their way. Their business was to find enough plants to nourish their gargantuan hulks. They raked in the green fodder with their blunt claws and teeth, swallowing it without chewing. In a gizzard-like organ it was ground with stones into a digestible mash. Such stones have been preserved between their ribs. Some palæontologists have thought of them as the world's most accomplished gluttons. Certainly they must have had the capacity for several hundred pounds of vegetable food each

day, but it is doubtful that their appetite matched their bulk. They were probably like living reptiles—cold-blooded, sluggish, and abstemious.

Despite their impressive architecture, these amphibious dinosaurs were weaklings. Their weight had increased far more than their strength. On land they were nearly helpless. It is surprising that they roamed so widely. Rising in some obscure flesh-eater of the Triassic they reached a climax in North America during the Lower Cretaceous period. By Upper Cretaceous time they had invaded South America, India, Africa, and Australia. Then, like Rome growing unwieldy to its fall, they sank into extinction.

While the carnivorous and amphibious dinosaurs were making their mark in the Mesozoic world, the dinosaurs with bird-like hips were writing their version of progress. They were plant-eating throughout their history and like their relatives of the crocodilian hips, they gave rise to a variety of forms, some of which were the most grotesque animals that ever entered the arena of life.

Only a few remains of these creatures are known from Triassic formations. They were slower in getting under way than their more aggressive relatives whose ethics condoned not only unfair competition but cannibalism as well. They began with small bodies equipped with both the hips and the feet of birds. The first good record of bird-footed dinosaurs was preserved in middle Jurassic rocks of western Europe.

One day many millions of years ago, a party of Iguanodons, first Belgians with serious pretensions, met with an accident. While exploring a deep crevice in the rocks, seventeen of the group were trapped. They died, were buried under the crumbling walls, and preserved through all the long ages that followed. Thus time distilled a blessing from misfortune and gave to science a remarkable record of a remarkable race.

Iguanodons were large animals over thirty feet long and a full fifteen feet high. Like the carnivores they walked on their hind limbs, although being heavier and less graceful, they occasionally dropped down on all four feet. They haunted the water of the marsh-lands, grubbing in the mud with horny duck-like beaks. Their teeth were numerous and suited to the business of shearing tough vegetation. Three toes fashioned into hoofs for running adorned their feet and a flattened tail helped solve the problem of locomotion in water. Their only weapon of defence was one peculiarly spiked finger on each hand, an instrument which thanks to their fleetness they rarely needed.

With time the duck-billed dinosaurs multiplied and spread in rich variety over the world. *Trachodon* from the Cretaceous of western North America is best known. He was both swimmer and runner *par excellence*. Several remarkable mummified specimens contain bones, skin, and traces of muscles and tendons. The skin was no thicker than that of a snake and was

guarded only by paper-thin scales. When *Tyrannosaurus* drew near, discretion was all that *Trachodon* knew of valour.

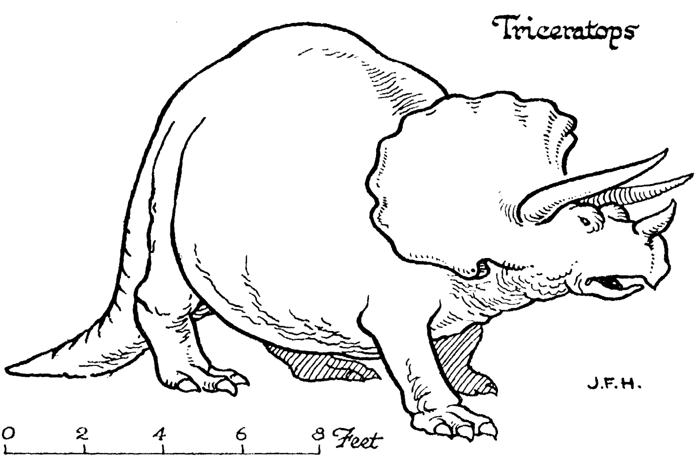
Like others of his kind he searched the sedgy bottoms of swamplands for his food. As with so many other bird-hipped dinosaurs the front of his jaws extended into a toothless beak. Behind, however, was one of the most impressive batteries of teeth ever lodged in the head of any animal. He could boast a full two thousand. They were beautifully fashioned for cutting coarse vegetation and when the ones in current use wore out, others rapidly filled the ranks.

From such creatures as these came dinosaurs who abandoned flight for armed resistance. Starting modestly with the protective scutes of an alligator,they gradually acquired bodies so massively armoured that against them *Tyrannosaurus* himself was no more effective than a mosquito on a tin roof.

Stegosaurus, pride of the armoured dinosaurs, appeared suddenly at the end of the Jurassic period. He was larger than an elephant and nearly as spiny as a horned toad. With his rump tilted to heaven, his nose to the ground, he worked his clumsy way over Europe and the United States. Great bony plates standing on edge ran in two rows along his back from head to tail. Horny nodules toughened his skin. Such has always been the nature of things that even in the soul of a vegetarian dinosaur, indignation must sometime rise. When crossed, *Stegosaurus* would turn

feet long and six inches thick at the base rose from the skull over each eye. A smaller horn graced the nose, and on the mouth was the beak of a turtle. Behind the head the body was unguarded.

The ceratopsia, alone among the vegetarian dinosaurs, were born fighters. The crests of some skulls had been punctured, perhaps by rivals in the



struggles of courtship. Many a skull gives proof of horns broken in battle and later healed, and epitomizes the eternal melodrama of existence.

One night some seventy million years ago the moon looked down at the earth. Where now Wyoming lifts its western borders to the sky lay the shorelines of an inland sea. Night air came sweet and heavy off the coastal marshes. Palms and evergreens stood quietly against the sky. Only *Triceratops* moved as he raked the sedges for food.

Suddenly the browsing dinosaur raised his head. Thunder was rolling somewhere in the sodden gloom, growing louder as it approached. A black cloud rose over a hillock and quickly shaped to the terrible form of *Tyrannosaurus*. One leap and the tyrant sank teeth and talons in the soft back of his victim, but not before the horns of *Triceratops* had found their target. Locked in the embrace of hunger and hate, they died. But the moon looked down unmoved.

Of all the herbivorous dinosaurs alive at the time, the ceratopsia alone were a match for the monster flesh-eaters. Perhaps that is one reason why both disappeared at the close of the era. Yet warfare among themselves cannot explain the passing of all the dinosaurs. Life has always meant struggle, but life somehow goes on. Nor can the attack of primitive sharp-toothed mammals on the eggs and the young of dinosaurs account for the removal of all their swarming multitudes. Near the close of the era continents rose high and standing waters escaped to the sea. The swamps where roamed nearly all known dinosaurs slowly passed away. Cold weather, ever a menace to reptiles, crept over the lands. There is no doubt that before the dinosaurs died their world had become unfriendly, but it is a mystery why some did not find haven somewhere.

Perhaps nature sets limits on the lives of races as on the lives of individuals. The saga of the medieval saurians was written with magnificent freshness of

detail and originality of characterization around a very stale plot. The rise of primitive creatures, their multiplication and diversification, their adaptations to special ways of living, and the death that follows, is the pattern to which the history of every race has been cut. Nobody knows why nature clings to this pattern.

Nobody knows why the dinosaurs sank into extinction, or for that matter, why they rose to power. The motives of nature are vague. We do know that they were the first conspicuously successful animals of the land, that the earth was theirs for more than fifty million years. They ruled longer than any other animals before or since, and they ruled successfully. Although æons have now rolled over their bleaching bones, the death that removed their flesh cannot remove their glory. Death is the price that all must pay for life. Because the dinosaurs led lives of richness within the limits set upon them they bargained well with fate.

XI

SAILORS OF FORGOTTEN SEAS

WATER is the womb of life. Until it came to the atmosphere and distilled into the parched hollows of the earth's surface, life could not have been born. The history of every race and every individual drips water. Its mothering vitality supplies flesh, food, and shelter. If it should leave the planet for a second, microbes and men would crumble to dust.

The organisms that crawled from the sea abandoned water only as a habitat. They never escaped the need of water for building and replenishing the tissues of their bodies. And even the most terrestrial of creatures have always been chained in one way or another to rivers, lakes, swamps, and the ocean.

The dramatic exodus of backbone from the sea did not leave the sea deserted. And the revolution that ravaged its denizens, that laid low entire families, did not kill all who had been deaf to the call of the land. The sea has ever defended a goodly portion of its brood from the lure of the outer unknown and the threat of death within. So it was that while the greatest creatures were making their individual reputations on land, the humblest were collectively building a monument in the sea. With the spreading of marine waters during Jurassic time, the one-celled

protozoans spawned billions on the friendly shoals. Some were lodged in beautiful little houses of limestone and glass, each smaller than a particle of dust, but endowed with the strength of ages. Death destroyed the living droplets and delivered the houses to wind, wave, current, and gravity. These draymen of a whimsical fate gathered their microscopic cargoes into heaps that stand today, defiant of ruin, on the elevated bottoms of forgotten seaways. We see them in the red flints and slates of the Alps, but especially in the Cretaceous chalk cliffs of Dover and Dieppe. We see them in the buttes as we ride under the moonlight over the desert plains of western United States, ghostlike remembrancers of a vanished fertility. So abundant are the deposits built wholly or in part with the skeletons of one-celled animals, that these individually insignificant but collectively impressive creatures give character to whole epochs of time, to whole series of rocks, and to vast areas of the modern earth. Thus through a whim of fate does glory sometimes fall with death upon the heads of the humble.

In sundry walks of marine existence, rehabilitation followed the tragedy of the Appalachian revolution. Sponges languished through the Triassic period but took a new hold on life in the Jurassic. They grew with profusion and diversity in the waters that turned the continent of Europe into an archipelago during the middle of the Mesozoic era. Everywhere in the Triassic, modern corals replaced the old-fashioned and rapidly disappearing Palæozoic varieties, and grew in

luxuriant reefs during the Jurassic and Cretaceous periods. Although death took most of the anchored spiny animals at the end of the Palæozoic, the unattached starfishes and sea urchins moved on. The latter rose to an excellence hardly suggested by their rare and primitive ancestors. The lamp shells never regained their ancient prestige, but the clam-like molluscs covered themselves with new shells and new glory. Oysters were the invertebrate pride of the seas. Never a race of high endowments, they made most of their meagre allowance during the Mesozoic era. Snails, too, were improved. Throughout the Palæozoic they had suffered the physical if not the spiritual discomfort of an anus too close to the mouth. During the Mesozoic many of them grew long tubes through which body waste was piped to a more comfortable distance from the intake.

Coiled cephalopods multiplied with a wonderful diversity of form and ornamentation. Like the lamp shells of the Palæozoic they were the most typical invertebrates of the Mesozoic. But towards the end of the era they began to disappear. Many uncoiled with the degeneracy of racial old age. All but the tenacious nautilus were gone with the passing of the era.

Their place has been filled in the present world by molluscs of more modern equipment. Following the successful fashion of the vertebrates, the ancestors of cuttlefish and squid wore their skeletons inside their flesh. They mark the turning of molluscan fortune.

In abandoning heavy shells they grew active and aggressive. Some of them carried ink bags and darkened the water when hard pressed by enemies. An abundance of the peculiar cigar-shaped remains of their skeletons proves their early success. Although all but one died with the close of the Cretaceous period, their descendants, the squid and the octopus, are the strongest backboneless animals in the sea today.

The powerful trilobites and sea scorpions of the Palæozoic were replaced by more familiar crustaceans during the Mesozoic. Long-tailed lobsters and short-tailed crabs were in every ocean. On every land swarmed many varieties of insects, especially in the Jurassic period, but the insects that live on pollen and nectar were not among them. Flowers had not yet come to the lands.

Sharks, so prosperous during the middle Palæozoic, were nearly bankrupt at its close. With the resilience peculiar to their tribe they rebounded into better fortune before the Mesozoic era was very old. Some hunted the easy game of the sea bottom until they grew flat and sand coloured. With teeth like a cobblestone pavement they crushed the brittle shells of their victims as a steam roller crushes gravel. Like shadows they moved among their unsuspecting fellows. Their treachery was successful and is still effective in the rays and skates of modern seas.

The lungfishes had apparently exhausted themselves during the Palæozoic era. They lingered on indifferently. The ganoids, too, dwelt beneath a setting star.

From them, however, came a new kind of fish, with all the cartilage of the ancestral skeleton replaced by bone. Rising in the Jurassic the bony fishes forged to the leadership of the piscine world. By Cretaceous time great schools of herring, cod, salmon had spread into every sea. The perch, the catfish, and other familiar fishes of today were also well established. The bony fishes were not only immediately successful but they did not once waver in their triumphant swim to the present.

Although many of the Mesozoic amphibians and all the reptiles were equipped with lungs and were free to spend their time in the air not all of them found happiness in their pursuit of it on land. Food was scarce. The lions got the lions' share and the sheep got shorn. To escape death, many of the weak returned to the home of their ancestors. And many of the strong were lured back to the water by their hereditary love of sea food. The dinosaurs themselves lurked in the swamps along low coasts, boarders if not roomers in the old home. Other reptiles became so completely readapted to life in the sea that not even the fishes excelled them in efficiency.

Some of the Mesozoic seagoing reptiles are among the most remarkable animals that ever lived. Lungs and legs, the greatest assets on land, are the severest liabilities in water. If other organs, particularly the nervous system, had not improved with their experiences on land, it is doubtful that any of the

homesteaders of the new environment could have returned to the old. Many of them did not venture beyond the shores of lakes, lagoons, and rivers except when approaching death drove them to desperation. Others paddled around and learned to swim. Some became so capable that they returned to shore only to lay their eggs. A few grew the fins of fishes and never came ashore. Like mammals they brought forth their young alive, and spent all their days in an element that could easily have drowned them in ten minutes.

When the primitive proganosaurs of the Permian period deserted the land for the sea, they demonstrated the hoary verity that realization is a poor match for expectation. The reptiles had just emerged from the water, a new world before them. The strong had not yet discovered the latent possibilities in the new environment and in themselves. But the weak have always been quicker to feel their limitations than the strong their powers. The proganosaurs soon knew that the land was not the California of their dreams. They could not make a decent living there, so they returned to the aqueous Iowa of their forbears. And in returning they led a procession of sadder but wiser vertebrates, a large and varied group of disillusioned adventurers. Since the Permian, twenty-five orders of backboned animals gave up the fight for a place on the land and returned to the ancestral sea. Seven of these were reptiles of a time when reptiles ruled the earth, protagonists of the age-old drama of cruelty so meagrely epitomized in " man's inhumanity to man."

Mesosaurus, best known of the Permian aquatic reptiles, seems to have preferred fresh water. He suggested a modern alligator, but his head and neck were longer and more slender, his teeth more numerous and needle-like. The hind pair of short limbs were tipped with broadly webbed feet. The tail was a long flexible whip. On land the forbears of this creature were merely additional reptiles in an overcrowded and underfed society. But in the water few could dispute their supremacy over the weaker fishes. *Mesosaurus* luxuriated in the rivers of Brazil and South Africa, a happy if not a progressive citizen.

With the coming of the Mesozoic era, seafaring reptiles rivalled the dinosaurs in abundance and size. The plesiosaurs thrived throughout the era. Over a hundred varieties are already known and new ones are being discovered each year. By Jurassic time there was not a sea that did not know them, although it was the Upper Cretaceous that nourished their most magnificent representatives.

A fat body and a long neck was continuously the most popular plesiosaurian figure. A turtle whose head and neck are the front two-thirds of a snake, and whose tail is the hind third, is an accurate if not lovely description of a typical plesiosaur. None of the various body forms of these creatures quite escaped the suggestion of this hybrid anatomical liaison.

There are two methods whereby water animals push themselves through their medium, the one by means of the tail, the other by means of fins or flippers. The

ablest masters of the first are the bony fishes. When the plesiosaurs left the land for the water they did not resume the wriggling motion of their ancestors, but used their limbs for locomotion and became the most efficient adherents to the second method. Whereas the fishes use the tail for propulsion and the fins for balancing and steering, the plesiosaurs used the limbs for propulsion and the tail merely for directing their movements. Such difference in habit effects profound differences in appearance. Tail-driven animals develop broad flexible tails and limbs of small and unequal size. Limb-driven animals grow inflexible rounded tails, and limbs that are large and nearly equal in size.

Because the plesiosaurs rowed themselves through the water, their limbs became broad flat paddles, modified, by the addition of bones, from the five-fingered hands and five-toed feet of their terrestrial ancestors. Short tailed water animals cannot turn quickly while pursuing their prey. They need long necks to snap up the dodging quarry. Nature gave some of the plesiosaurs the longest necks on record. *Elasmosaurus* had twenty-five feet of head and neck to sixteen feet of body and tail. In giraffes the neck is lengthened by the lengthening of the seven neck vertebræ. The plesiosaurian neck grew long by the addition of new vertebræ. One type could boast a neck of seventy-six bones, perhaps the most magnificent ever constructed. But others had to be content with necks shorter than their heads and containing as few as thirteen vertebræ.

Nearly all the plesiosaurs had small snake-like heads with stiletto-lined jaws. They ripped their food as crocodiles do and never bolted it whole after the fashion of snakes. They swallowed pebbles to grind the shells and bones of their victims to an assimilable mash. One plesiosaur found in Kansas contained pebbles from South Dakota, thus proving himself a strong swimmer who had roamed widely. The bones of these creatures are known from every continent in the world. They were almost perfectly fitted to life in the sea, capable of overcoming any imaginable enemy, capable of swimming away from any conceivable threat in the physical world. Yet like the dinosaurs, they vanished completely with the turn of the era.

Splendid as were the plesiosaurs in their adaptation to life on the high seas, the supreme reptilian sailors of the Mesozoic were the ichthyosaurs. These "fish reptiles" so perfectly assumed the body form of a fish that more than one naturalist believed them the offspring of fishes. We now know that every fundamental structure of their body was reptilian, that their fish-like form came only after they went down to the sea and improved with the extension of their sojourn there.

Unlike the plesiosaurs, the ichthyosaurs wriggled through life. With the perfection of this mode of locomotion came the perfection of the ichthyosaurian tail. The earliest forms had long slender tails imbedded in narrow fins. Later the tail grew shorter

and the fin at its end became shorter and higher. Finally the tail fin became symmetrical. Although ichthyosaurs and fishes are totally unrelated in blood, tail fins came to fishes in much the same way, a response to the same manner of swimming.

The entire body was modified to move through water with the least possible resistance. Head and jaws grew longer, neck and tail shorter. Eyes, in some forms as large as a human head, were efficient lookouts for food and danger. As many as two hundred teeth in jaws fully five feet long kept the wolf from the door. The limbs became paddles as in the plesiosaurs, but the front pair grew much larger than the hind pair. Both were used for balancing, reversing, and turning.

By Upper Jurassic time the seas were full of ichthyosaurs from two to forty feet in length. Their bodies were smooth and supple. They skimmed the water as gracefully as the modern porpoise and like porpoises they travelled in schools. No sea was too deep or too wide for them, no storm too turbulent. They were perfectly fitted for the lives they led. Several fossils of female ichthyosaurs who had died in pregnancy show unborn young in the ovaries. In one case seven embryonic ichthyosaurs, all unmutilated and of similar size and species, were preserved within the ribs of their mother. An abundance of such evidence proves that ichthyosaurs had abandoned the normal reptilian habit of laying eggs on land, to give birth to their young alive at sea. They never needed

to come ashore, and probably never did. This was the last item in the evolution of perfect sea-worthiness. Nature had done the impossible. She had taken a vehicle of the land and had made it into one of the finest vessels that ever sailed. And then with consummate and unparalleled irony she sank her beautiful creation to extinction, a deep that knows no salvage.

Crocodiles today enjoy the leadership of the reptilian world and demonstrate the relativity of glory on earth. During the Mesozoic era when great reptiles abounded everywhere, crocodiles were no more important than a fifth hand at bridge, and far less obtrusive. Most of them lived quietly enough along the borders of lakes, rivers, and the sea, wallowing in sour pools, laying their eggs on land.

One group of crocodiles, alone among their numerous breed, caught something of the spirit of the times and distinguished themselves. Living first in the muddy water of large rivers like the Mississippi, they wandered into the open ocean. Their skin lost its bony armour, their teeth became sharpened for catching the swiftly moving fish of the sea, their bodies lengthened. A primitive fin for swimming grew at the end of the tail, and the front limbs were moulded to crude paddles. Because they never acquired the ability to give birth to their young alive on the high seas, their hind limbs retained the unwebbed toes of land animals. They ventured, but not enough.

Never a match for the plesiosaurs and ichthyosaurs, they soon died.

Turtles are perhaps the most unappreciated of earth's children. Nobody is interested or much amused at the sight of a turtle, yet turtles are perhaps the weirdest of backboned animals. Their shell results from the fusion of a sprawling backbone with the ribs. When a turtle pulls his head, feet, and tail inside his shell, he is entirely surrounded by ribs, a feat no other creature has ever been able to perform. Then, too, turtles are distinguished for the utter dullness of their long racial history. They appeared in the Triassic, ready-made as it were, and plugged stolidly to the present. Furthermore, they are the only reptiles beyond the threat of toothache, for their ancestors lost their teeth long æons ago. And lastly, turtles deserve a better place in the world for their unmistakable physiognomy. A person who cannot distinguish horses from mules can always recognize turtles.

Although lovers of marsh and river, the turtles have never been without their ambassadors to the sea. Toward the close of the Cretaceous period, a group of turtles became so successful in the sea that their bodies grew to the length of twelve feet and to the weight of over three tons. Part of the shell disappeared for freer movement and the front legs enlarged to great paddles. The modern marine turtles are descendants. They come ashore only to breed. Enemies await their landward migration and many

lay down their lives with their eggs. It is said that the males of some species, who certainly know little of chivalry, never come ashore.

Nearly all living reptiles are either snakes or lizards. Diverse in form, they are united in the possession of uniquely movable mouths. The lower jaws are joined to a pair of bones which allow considerable forward, backward, and sidewise movement. Snakes did not arrive until late in the Cretaceous period. Most of them lived on the land, although they probably knew how to climb trees and how to swim. The marine snakes, such as those of the Indian Ocean today, are apparently a modern innovation and are poorly recorded in fossils. Lizards likewise began their careers in the Cretaceous but, unlike the snakes, they gave rise to a tribe that stands with the mightiest of the earth's inhabitants.

The mosasaurs or marine lizards of the Upper Cretaceous were the wildest nightmare of a medieval sailor come true. Like other great reptiles of the sea, they came from the land. Some were forty feet long, with large heads and mouths armed to the limit with vicious recurving teeth. Their jawbones were jointed in the middle so that the happy possessors could swallow objects greater in circumference than themselves. No other water animals have ever possessed the strength of these marine monsters. Their bodies, with short neck and long tail, were slender, built for speed. Before their attack the strongest fish fell easily, the fleetest was quickly overtaken. Grace,

strength, and agility found their finest embodiment in the mosasaurs. They cut a wide swath but a short one, for they were all gone before the close of the same period that saw their arrival.

And with the passing of the mosasaurs passed the glory of the seas. Never again was ocean to nourish such a richness of splendid creatures. Mystery shrouds the birth and death of these ancient mariners. We know that most of them came from the land, but we know neither how they came nor why they went, nor why their magnificence was never seen again. Many of them died and left no offspring species. A few are remembered in vastly inferior descendants. For those not entirely averse to parables from palæontology, the shadow of significance can be discerned behind these facts. The mightiest denizens of the Mesozoic seas were born of failure on land. They turned to the water for ease and peace. This they found, but not one of them gave rise to a creature better than himself. In a world that decrees the everlasting divorce of progress and happiness, they chose to be happy. Today they are gone and all but forgotten, yet who can say they did not choose correctly?

XII

PILGRIMS OF THE AIR

THE land of dreams come true lies just beyond the horizon. Protoplasm, stirred ever by the ferment of desire, reaches for that which it does not have. Sea and earth have never calmed the restlessness of flesh. After rising from the ocean to the conquest of the land, backbone yearned toward the wider pastures of the atmosphere.

From fish to man all classes of backboned animals have tried to fly. Over thirty different attempts have been made since Permian time. Because air is light and bones are heavy, failure mars the history of aviation. No creature has ever reached the zenith of aerial ambition, the ability to dispense entirely with the earth's surface. The finest flyers of every age have had to return to trees, land, or the sea for rest.

The less adept have never excelled the performance of an engineless gliding aeroplane. Some merely jumped from the trees and tobogganed to the ground on sustaining membranes. Others learned to sail on the breeze. Only a few developed true flight through the flapping of wings.

Today all degrees of flying ability can be seen among backboned animals. Every tropical sea has its flying-fishes, driven into the air by the relentless

pursuit of albicore and tunny. These remarkable little creatures can move through the thin ocean of the atmosphere for a distance of a few hundred yards before they fall back exhausted into the more substantial ocean below. Not infrequently they rise high enough to ground on the deck of a passing ship. The thrust of a powerful tail shoots them out of the water. Aloft they travel partly by vibrating their huge front fins, partly by soaring on favourable breezes. Ten times since their origin fishes have sought safety in the air. Never the best of flyers, they are far from the worst. That they should be able to fly even a little is noteworthy, because they cannot breathe out of water.

Amphibians, congenital lovers of the slime, are not totally without aspiration. The tree frogs deserted the marshes for wider but more hazardous prospects in the tree tops. Nature condescended to strengthen a precarious foothold by tipping each finger and toe with an adhesive pad. She spread membranes over each hand and foot to serve as crude parachutes when the animal leaped from branch to branch. Tree frogs at best are but poor gliders. Their sustaining webs never exceed three square inches. Yet in them lies the suggestion of the possible origin of wings.

The flying dragons of Malay are little lizards whose ribs extend on either side to support a pair of wing-like membranes. When resting amid the foliage of the tropical forest they shut their "wings" like fans against their bodies. Before leaping they spread them,

and partly glide, partly fall to their destination. In other reptiles a frill of leathery skin, unsupported by bony framework, runs horizontally around the body. None of these animals can really fly. Their " wings " make them nimble in the trees and often help to break a fall, but they do not bring their owners to the status of true aviators.

Alone among backboned animals birds took to the aerial life from the beginning, and with few exceptions adhered to it throughout their history. The ostrich, the penguin, and a few others make no attempt to fly, whereas birds like the barnyard hen will occasionally rise into the air for short, laboured excursions. But the unique possession of feathered wings keeps most birds aloft. Long before human aviators vied for speed, endurance, and distance records, birds had attained a high efficiency in every phase of flying. A house swallow has maintained a speed of two and a half miles a minute for several minutes. An albatross had flown more than three thousand miles in twelve days. Vultures and condors had risen over two miles in the air and had soared on the thin atmosphere over lofty mountain peaks.

Not to be outdone by fellow vertebrates, mammals have repeatedly rigged themselves for flight. Today several varieties of tree-dwelling mammals are equipped for gliding with skin membranes that stretch between their front and hind limbs. Flying squirrels, opossums, foxes, and lemurs are abundant in tropical forests, and their efficiency as aeronauts approximates

that of their neighbours, the flying dragons. Although thirteen different mammals have looked to the sky, only one has ever acquired a satisfactory flying mechanism. The bat alone grew true wings with the power of sustained flight. He is the only creature whose wings are supported by the elongation of the fingers. Most grotesque of flyers, he nevertheless is second only to birds among the backboned hunters of the air.

Only three times has the desire to fly led to the growth of organs adequate to its indulgence. Birds and bats are breathing monuments to the latter two conquests of the air. The first conquest is remembered only through the bones of animals who died without issue many æons ago.

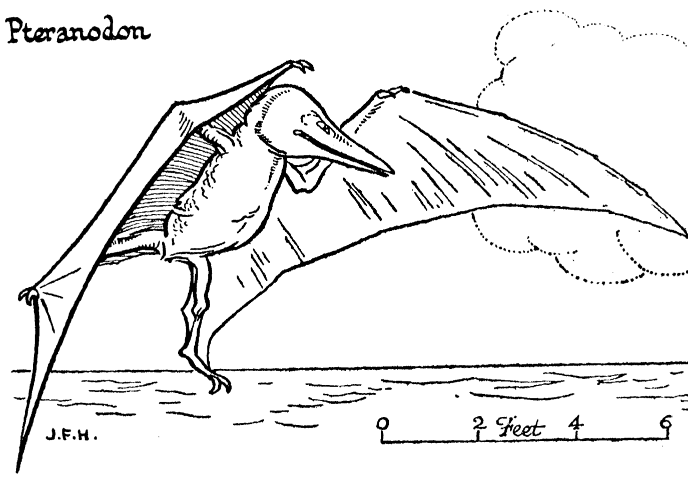
Near the end of the eighteenth century, when Frenchmen were murdering each other with the customary enthusiasm of the human spirit inflamed, Cuvier was quietly at work in his Paris laboratory with the hope of raising from the dead a creature long forgotten. Patiently he was piecing together some remarkable bones found imbedded in the lithographic limestone of Solenhofen, Bavaria. In 1801 he announced the discovery of an extinct animal whose appearance approached that of the imaginary dragons of mythology. He proved the magnificent organism a member of a hitherto despised race, a race of loathsome, crawling, poisonous creatures. Since then many men have enlarged our knowledge of flying

reptiles. Today the pterosaurs and pterodactyls, as they are variously called, stand with the best known of animals. They are undoubtedly the most curious anatomical assemblages the hands of a whimsical inventor ever fashioned.

From the beginning of the Jurassic until the middle of the Upper Cretaceous periods, pterosaurs enforced reptilian mastery in the air. They rivalled the dinosaurs in number and variety. Some were as small as sparrows, others were the greatest animals that ever moved on wings. All had comparatively small bodies whose bones were filled with air instead of marrow. The fourth fingers were enormously extended to support a pair of leathery wings, naked like the wings of a bat. The other three fingers of each hand stood free from the wings, and were used as claws when the animal climbed among the branches. The head was ludicrously long, armed with many slender teeth for spearing fish. Some pterosaurs favoured a long tail with kite-like tip, others a short tail, and a few struggled through life with no tail at all. Some carried large eyes for nocturnal hunting, others flew by day. They were unanimously devoid of scales, feathers, or hair. Most were as able on the wing as modern bats, and superior to the primitive birds with whom they lived. Some adventured far over the sea and finally dropped their bones amid those of marine reptiles.

In making the pterosaurs, nature took liberties with the reptilian body. Every organ was altered for flight. Skull and backbone remained very similar to

those of other reptiles, hip bones were quaintly like the hip bones of dinosaurs. Brain, lungs, breastbone, and shoulder girdles were similar to those of birds, although pterosaurs and birds were unrelated in blood. Their structural similarity derived entirely from a similarity of habits. The pterosaurian neck with its seven vertebræ was like the neck of a mammal. No other creature has ever possessed a similar combina-



tion of diverse characteristics. Such a skeletal hodge-podge would have been ridiculous had it not been so successful.

Pteranodon from the Upper Cretaceous of Kansas marks the acme of attainment among flying reptiles. With a wing spread of twenty to twenty-five feet, this creature was the largest animal that ever flew. One of his wings could cover the greatest living bird. Every detail of his skeleton was fashioned for flight.

Wings, shoulders and breastbone were powerful, but the nether body was weak. Hind limbs were spindling and probably seldom used. At rest *Pteranodon* clung like a bat to cliffs and trees. His head was four feet long and narrow, nearly perpendicular to the backbone. In front of the neck were toothless jaws and a sharp beak; behind was a long extension of the skull for counterpoise and steering.

Despite his great size, *Pteranodon* weighed less than thirty pounds. It is estimated that he used only thirty-six thousandths of a horsepower in flight, whereas Langley's first aeroplane required one and a half horsepower for every thirty-eight pounds of weight. Although an efficient flyer when once in the air where he could utilize the wind in the manner of modern gliding aeroplanes, *Pteranodon* may not have been able to launch his great body on a still day. Like the albatross he hunted fish over the sea.

Pterosaurs came fully developed with the Jurassic period. Except for a general loss of teeth and tails, they did not change to the day of their final disappearance. There is no clue to their ancestry other than that it must have been reptilian and distinct from the stock that mothered the birds. Before the close of the Mesozoic era the curse that nature had pronounced on reptiles removed the pterosaurs as abruptly as they had appeared.

Even while the pterosaurs were spreading triumphant wings over the whole earth, another band of reptiles

was learning to fly. Hidden in the back eddies of Mesozoic life these creatures were quietly experimenting on a new idea. With the modesty befitting greatness, they eventually sent their envoys, the first birds, into the main stream of life. Under the shadow of the pterosaurs the little avian prototypes did not loom to their full importance. Only after the wings of the last flying reptile had ceased to vibrate was it clear that the birds had been chosen as the aviators of the future.

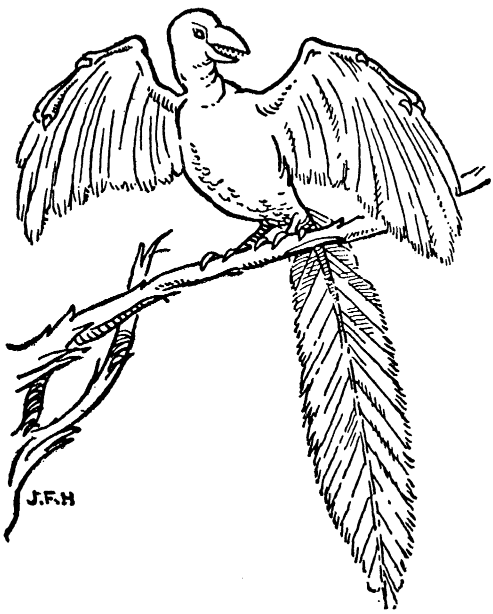
The origin of feathered flight is almost entirely a matter for conjecture because the ancestors of the animals who first developed it are lost in the fogs of time. There is a striking similarity between the hind limbs of birds and those of the fleet-footed dinosaurs, enough to remove any doubt that both were descended from a common stock. Some authorities believe that running and jumping over the ground eventually led to soaring and flying in the air. Others believe the forbears of the birds to have been climbing animals who, like the flying squirrels, glided from branch to branch with the aid of sustaining membranes.

The energy that drives animals into the tree tops might be expected to drive them into the air. Because nature fits her children for the lives they lead, it is logical to suppose that animals who jump about in the trees might be the first candidates for a course in flying. The lizard-like ancestors of the birds may have acquired upright carriage through swift running over the ground, but it is reasonable to believe that

they adopted flight only after taking to an arboreal life, wherein flying is safer and easier than running.

So it may have been that the proavian, venturing wider and wider leaps, found his scales growing longer wherever the pressure of the air was strong. His

Archæopteryx



arms, outstretched for each jump, became parachutes that caught more and more air in the lengthening and overlapping scales. The tail also sprouted giant scales where its edges cut the air. In time friction frayed the ends of the scales and feathers came into existence. The toes and fingers of a climbing reptile

grew into the claws of a primitive bird. Flight developed powerful muscles for flapping the arms, and enlarged the breastbone to support these muscles. Increased activity and the slow spreading of the feather blanket raised the temperature of the blood. The lungs expanded and filled the bones with air. Time and his faithful attendant, failure, passed by, but in their wake a bird was confidently flying.

One hundred years of search have failed to discover the slightest trace of a bird in rocks older than the upper Jurassic. *Archæopteryx*, the earliest fossil bird known, broke into the geological record of that period in full feather. The only certainty of his origin is that it was reptilian but quite independent of the flying reptiles.

He was no larger than a crow. His head was small and flat, different from the head of any living bird. Of all the many thousand species of birds on earth today, not one has a tooth in his head. The sharp teeth in both jaws of *Archæopteryx* were revealing relics of a reptilian inheritance. So too were the free clawed fingers of each hand, not yet fused as in modern birds. A weak breastbone and a long reptilian tail which had not yet become fan-like testify to a short racial history in the air. But the feathers on wings and tail make *Archæopteryx* a bird. No other kind of creature has ever grown these unique appendages.

Although only two specimens and a lone feather remain to commemorate the founders of a great dynasty, a multitude of reptilian birds must have been

alive in the Jurassic period. Bird bones are fragile and they easily fall to the attack of weather before burial and fossilization are possible. Numerous animals feed on dead birds and help to rob the rocks of their record. The primitive birds were haunters of tidal mud flats and coral reefs where they preyed on fishes moving over the shoals. Many must have died on the water where their buoyant carcasses rotted in the sun or were devoured by marine scavengers. The fact that the two known specimens of *Archæopteryx* are of different species argues other species and countless individuals astray in the Lethean depths of time.

The Jurassic sea had flooded the lowlands, carving the country into a thousand islands. Under the shade of cycads and yews, ferns and mosses grew where hardwoods and grasses would grow today. Beyond the white collar of froth left on the island shores by breaking waves, coral colonies had built many a reef in the warm blue water. Sea-shells of all shapes and colours lay in the translucent depths. On the landward side of every reef lazy saurians took the sun. Occasionally a troop of ichthyosaurs charged by in pursuit of a school of fish.

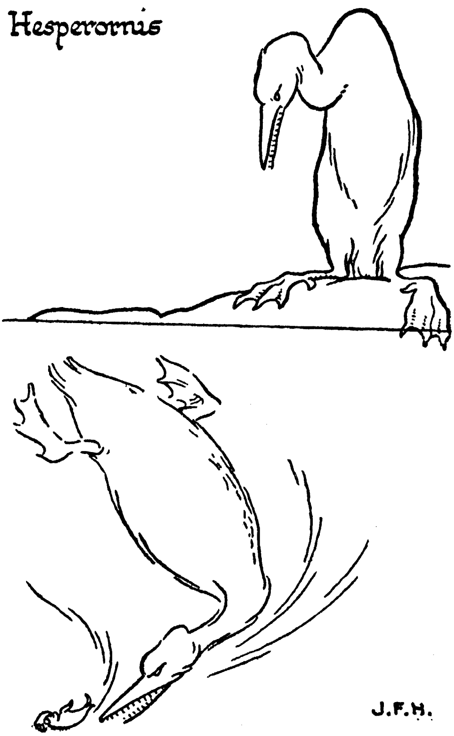
In the air great pterosaurs glided on the breeze, now circling toward the sky, now skimming the water, now thrusting a dagger-like beak toward an unsuspecting fish. Among the palmy branches of the cycad trees the feathered *Archæopteryx* was about his business, awkwardly flapping after insect tidbits, croaking an ugly song to an ugly mate, scattering the feathers and

the blood of a rival, or merely clinging to a branch and gazing over the sea. Had he been sentient, he might have admired the beauty of the scene, the glory and diversity of its people, but he could not have prophesied the day when all of what he saw would be gone—all but a few diluted drops of his own blood.

Great as is the gap between *Archæopteryx* and the reptiles, it is scarcely greater than the hiatus in the record of birds after *Archæopteryx* had passed away. For several million years not another bird is known to have been preserved as a fossil. Then, before the end of the Upper Cretaceous period, nature vouchsafed the story of *Ichthyornis*, a bird about the size of a pigeon. Except for the generously toothed jaws and the fish-like vertebræ of the backbone, *Ichthyornis* was disappointingly like a modern bird. He had lost the clawed fingers of his ancestors and the unnecessarily long tail. Well developed breastbone and shoulder girdles prove his aptitude for flight. He was a fish-eating sea bird like the living gull, thoroughly modern in habit but blending in his bones the old with the new.

Hesperornis, bird of the west, lived with *Ichthyornis* along the Cretaceous shorelines of Kansas. He was a powerful diving bird with the general appearance and habits of a loon, but over twice as large. Through swimming his wings had all but disappeared, his feet had become broadly webbed. So devoted was he to the water that he lost not only the power of flight but

probably of walking as well. His unique distinction among water birds of all time was that he paddled with a sidewise rather than an upward and downward motion of the legs and feet. A modern duck bicyclès through the water, but *Hesperornis* rowed, feathering his feet as a good oarsman feathers his oars.



With *Hesperornis* the first chapter in the history of aviation came to a close. Twice the cold reptilian spirit had felt the exaltation of wings and twice the air had failed of its promise. The close of the Mesozoic saw the last pterosaur in his grave and the finest bird

a wingless degenerate. But flight did not disappear with these flyers. The difficult and the remote continued to lure the children of flesh. Although pilgrimage to the sky will doubtless always offer the hope of fulfilled desire, the earth may be expected to cling to what is rightfully hers. If she cannot hold her sucklings in life, she can at least in death gather them once more to her breast.

XIII

TIME BREWS A CHANGE

EVEN while nature was strengthening the teeth, fins, and wings of reptiles for their dictatorship over land, sea, and sky, she was grooming others to succeed them. It is her way. Her plan requires that success and failure shall alternate. Always in the shadow of the great are creatures who remain unchanged while æons roll over their heads. They are the conservative, unambitious ones who only stand and wait. But in time they inevitably get their chance. Rulers are seldom concerned with threats whispered in the dark alleys of their domains. Man bodes little ill from the buzz of an insect, and would scoff at the suggestion that insects may some day take his place. The Mesozoic reptiles, had they been of a scoffing temperament, would certainly have derided any imputation of danger in the puny mammals beneath their feet. But the mammals eventually succeeded the reptiles, and the insects may eventually succeed man.

The commonplaces of mammalian anatomy and physiology, so conspicuous at zoos and bathing beaches today, were rarities during the Mesozoic era; yet every fundamental characteristic of the mammalian body existed at that remote time. Perhaps during the turbulence of Permian days and long before their

kind usurped the earth, a band of reptiles had wandered into a strange evolutionary pathway to emerge profoundly changed. They were the dog-toothed reptiles whose bones were preserved in the Triassic rocks of South Africa. Their teeth, unlike those of fellow reptiles, were differentiated into incisors, canines, and molars like the teeth of mammals. The bones through which the skull joined the spine, as well as certain parts of the jaws, hips, and limbs were strikingly mammalian. These animals prophesied the anatomy of a new day, and it is believed that their undiscovered ancestors were also the parents of the first true mammals. At any rate, the dog-toothed reptiles and the primitive mammals whom they so closely resembled, appeared at approximately the same time and in the same locality.

When Permian deserts forced most reptiles off their complacent bellies to run on their legs after water and food, the occasion was made for the development of warm blood. Running raised the temperature of the body. When Permian glaciers devastated the lands of the southern hemisphere and threatened all cold-blooded animals with extinction, the best possible incentive for the retention of body warmth was supplied. Friendly climates alternated with hostile, and thawed out some of the reptiles who had chosen to risk death by hibernating through the long winters. They who escaped with their clamminess intact carried on the cold-blooded reptilian tradition. The more progressive, however, responded to the menace of a

capricious environment by giving issue to the dog-toothed reptiles on the one hand and to the warm-blooded mammals on the other.

The greater activity of mammals gives them their undoubted superiority over reptiles. Their longer legs, their hair, their flexible jaws, but particularly their four-chambered heart, warm blood, and highly sensitized nervous system came to them because they were able to throw off the ancestral lethargy. In every detail of anatomy, the mammal represents the perfection of the vertebrate body. The earliest mammals were hatched from eggs like most reptiles and all birds, but the hazardous old-fashioned habit of egg-laying was slowly abandoned for direct birth and care of the young. The duck-billed mole and the spiny ant-eater of Australia are anachronisms in the modern world because they enter it through the cracks in an eggshell. All other mammals are born alive. Of these the marsupials are most primitive. Female kangaroos and opossums deliver their young in an immature condition and must fasten them to paps in an abdominal pouch where they can grow until strong enough to enter the world. By far the greatest number of living mammals are brought to a relatively mature state before birth. The mammary glands, from which the class is named, secrete milk when the females are nursing their offspring and serve the post-natal phase of an elaborate and distinctive method of reproduction.

The mammalian body is completely divided by the

diaphragm, a muscular membrane in front of which lies the thoracic cavity with heart and lungs; and behind, the abdominal cavity with digestive, excretory and reproductive organs. Most mammals have two sets of highly differentiated teeth. The temporary milk teeth of youth eventually fall out and are replaced by the so-called permanent teeth (which unfortunately may also fall out). The nervous system, attuned to the exigencies of an active life, is the finest in the whole animal kingdom. Just as the birds, through running vigorously on their hind legs, eventually rose on wings above their sluggish parents, so the mammals, running on four feet, eventually left their ancestors far behind. They not only weathered climates that reduced the reptiles to a sorry band of survivors during the Cenozoic era, but they entered and possessed every realm. And in time they gave birth to humanity, which (no man at least will dispute) was the finest accomplishment of half a billion years.

But in the beginning mammals led a lean existence. During the Mesozoic era they were squeezed under the reptilian heel. They appeared late in the Triassic period and left their bones in the record of many ages and places before the close of the era. Scarcely as large as rats, they lacked the compensation of a rat's audacity for their insufficient bodies. In a world that belonged to the reptiles they made their way by discretion, living in nooks and on food too trivial to draw the attention of the scaly overlords. Although their story is poorly known, it is clear from their teeth

that the primitive Mesozoic mammals had developed a variety of feeding habits. Perhaps most of them climbed trees and ate seeds, fruits, and nuts. Others searched the hummocks of the marshlands for succulent grasses and roots. Some sought worms, insects, and the eggs and young of birds and lizards. Theirs were the byways of the world and the scraps from the reptilian table.

Mammals remained small, primitive, obscure, and stagnant throughout the Mesozoic era. A remarkable discovery of mammalian jaws and teeth in Lower Cretaceous rocks of Wyoming vividly illumines the terrors of those unhappy days, when little furry creatures trembled in their jungle hiding places, hoping to escape the eye of a death that stalked at all times and in all places. For with their bones was the lone tooth of a flesh-eating dinosaur, sharp as a knife and edged like a saw, many times larger than the entire jaw of any of the mammals. With such neighbours it is not very surprising that the Mesozoic mammals were unprogressive. It is more surprising that they were able to exist at all. Most surprising is the fact that in them was the germ of a new empire, patiently waiting its day to be born.

While the animals of a new era were biding their time, the plants were fearlessly preparing garments for the day of liberation. Plants, though traditionally unassuming, are always a step ahead of their animal associates. In the beginning the primeval vegetation

made animal life possible by supplying food and shelter. Never since have animals freed themselves from this original dependence on plants. Animals would not have travelled far on land had not plants been there before them. And the hordes of browsing and grazing mammals that swept over every continent with the coming of the Cenozoic era, would never have shown their faces had not the plants prepared juicy leaves and grasses for them to eat. Quietly the plants view the life drama from the wings, content to let animals strut and mouth on the stage. The animals draw the applause, but the plants write the lines and set the scenes.

With the passing of the early epochs of the Mesozoic era, the spore-bearing ferns, club mosses, and horsetails that survived from the destruction of the Palæozoic forests never regained their lost magnificence. The underling seed plants of the old world became the masters of the new. Cone-bearing evergreens defied the cold and dusty uplands where they grew in dense forests throughout the Triassic and Jurassic periods. Ancestral sequoias, yews, cypresses, cedars, and pines established a strong foothold in many places. The ginkgoes reached the climax of a long career.

The cycads and cycad-like plants were the vegetable rulers of the early and middle Mesozoic; and if the era had not been named the "age of reptiles," it must surely have been called the "age of cycads." Cycads came through dark channels from the seed ferns of the Palæozoic. They are known sparsely in the Permian,

but during the Triassic they over-ran the earth from Greenland to Antarctica, and from California around the globe to Maryland and Mexico. So great was their success that for every three plants of different breeds there were two cycads. This ratio persisted as an average throughout the Mesozoic era.

Like their modern relatives, the sago palms of tropical forests, the Mesozoic cycads were squat trees that hugged the ground. The fat globular trunks of fossil cycads have been found in many places. They are characteristically scarred by pits out of which the long inflexible leaves once grew. On smaller branches wedged between the bases of the leaves were large flowers, beautiful beyond the perception of the world they graced. They were heralds of a brighter day, for in their central seed cone surrounded by stamens as well as sepal- and petal-like organs, was a prophecy of the early arrival of true flowering plants. Nature, as if proud of her creation, allowed a generous record of these quaint and lovely trees. Delicate unborn leaves, seeds with their embryos, pollen and flowers have come to the present age in perfect preservation. Such structures contain abundant vestiges of a fern ancestry, although their most striking attributes are those which they share with their modern descendants. The ancestral cycads bridged the abyss between the old and the new fashions in plants, and made possible one of the most significant events in earth history.

Like the mammals among animals, the flowering plants were the last to appear on earth, the most highly

organized, and the most successful. Today they constitute over half of all living plants. It is they who make the country beautiful with their green foliage and their gay flowers. It is largely they who feed both animals and men. From the equator well toward the poles, from the mountains to the sea, they cover the earth with a variegated spread of forest trees, shrubs, herbs and grasses. They even compete with the algæ for a place in streams and lakes, and a few have successfully returned to the ocean.

The early struggles of plants to leave the water and to make a safe home on the dry land built the strength that could mother an illustrious progeny. Out of the long travails of their ancestors, the flowering plants grew to a new excellence. Their bodies represent the perfection of a reproductive mechanism that had been on the make since plants first risked death out of water. The seed, developed originally by the seed ferns of the Palæozoic, became better and better adapted to terrestrial usages. Conifers, cycads, and related types grew seeds that were really the greatly enlarged female spores of ancient fern ancestors. Within the top of each seed a little water or a sticky fluid stood ready to catch the tiny male spores or pollen when they entered through the open husk that guarded the precious instrument from a harsh, hot world outside. A mating consummated, the husk fell from the seed and a new tree began its struggle for a place in the sun. With time and under the stimulation of prolonged desert climates, more and

more of the early stages of growth took place in the seed before the husk fell off and laid bare the tender embryo tree before the hazards of independent existence. By this means, less and less water was needed to establish the young plant. Every step in the improvement of the seed was a step away from the ancestral dependence on water. The last step of the long triumphal journey was taken during the Lower Cretaceous period when the flowering plants introduced a seed that approached perfection.

In this seed the edges of the coat of mail that guarded the female reproductive organ were joined to form a closed vessel. On top was a sugary fluid to catch and nourish the vagrant male pollen cells. Once captured, the pollen bored through the husk and impregnated the ovule. By this ingenious method the early water stages in the growth of primitive vegetation were completely eliminated and the young plant was given a better start in life than had ever been possible before. Wind took the place of water in bringing male and female together. The reproductive process was housed in flowers whose odour and nectar attracted insects to assist in fertilization.

The wheels of time seem to move slowly when the movement is measured by the span of a human life. It is impossible, for example, to imagine the duration of man's sojourn on earth. Yet man's rise from the brute seems rapid when compared with the time that has slipped by since the first live things began to stir. And similarly the spread of flowering plants was

inconceivably slow by one measure, by another almost instantaneous. If all known time from the birth of the globe had been but a year, the flowering plants would have appeared overnight.

By the end of the Lower Cretaceous period they had roamed from the old lands of their birth along the eastern coast of North America to South Dakota, Greenland, and Portugal. They were so abundant that the exotic character imparted by the cycads to Triassic and Jurassic landscapes was destroyed. The Lower Cretaceous vegetation was almost too familiar to be interesting, for it consisted of plants very similar to the plants of today. Sassafras, willow, oak, elm, poplar, walnut, maple, eucalyptus, fig, magnolia, laurel, cinnamon, and tulip trees closely resembled their modern descendants with similar names. The insects that hovered over them were like modern insects.

Under the almost world-wide uniformity of subtropical climate during the Upper Cretaceous period, the flowering plants took a place in the world that they have never since relinquished. They divided into two main groups, the one containing most of the forest trees, the other the grasses. The fruits and nuts of the former, and the grain of the latter were the most generous gifts that plants have ever offered to animals. If the reptiles had learned to utilize these riches their future might easily have been different. But the revolution in the vegetable world passed with the reptiles asleep to the new opportunities. The

Cretaceous is perhaps the only period in the history of the earth when vast quantities of animal food went begging. But the day was soon to come when the mammals would be free from the reptilian yoke, at liberty in a world that could not have been more propitious had it been made expressly to their order.

Unfortunately the earth does not normally deport herself for the happiness of the mites that crawl on her back. They must shift with her moods and her movements as best they can. Life has always meant adjustment to the ungovernable, and no freedom can offer more than a choice as to the manner of the adjustment. Even the vaunted power of man, when critically scrutinized, is a puny thing in a cosmos that allows its forces to be a little understood, a little used, but never even a little changed. The titans beneath the crust of the earth are likewise beneath the lives of all her creatures, the invincible masters of fleshly fate. Their paternalism may be benevolent, as when through the long dull æons of the Palæozoic era, it suffered the protoplasm to spawn widely in uninterrupted content. It may be cruel, as when at the close of that happy era, it hurled plutonic bolts at the world above. Benevolent or cruel, the lords of the abyss are the ultimate arbiters of fortune.

The revolution that dispelled the peace of the Palæozoic era with a discharge of underworld fireworks, raised all continents high and dry above the sea. The focus of events was shifted from the oceans to the

lands. Throughout the Triassic and well into the Jurassic, erosion was the dominant geological process. Eventually the sea began once more to creep over the land, especially in Europe, Asia, and far western North America. Great troughs became the sites of heavy sedimentation. Underneath, stresses again accumulated and found partial relief at the close of the Jurassic period. On the Pacific Coast, the Sierra Nevada, Cascade, Klamath and Coast Range mountains began to rise, and farther east the Rockies humped their backs a little higher above sea level. From lower California to Alaska hot rocks oozed from the interior and disfigured the surface with a multitude of volcanic sores. In British Columbia and Yukon a mighty pool of liquid rock congealed just under the crust. It stands today, bared by the wear of rivers and frost, a homogeneous mass over one thousand miles long, the largest single rock formation known.

During the Lower Cretaceous period, the sea extended its conquests over the land. Between the young mountain ranges of western North America a bay of ocean water found a new resting place. The Gulf of Mexico sent a moist tongue across Texas as far as Kansas and Colorado. Vast swamps, rich in the spoor of dinosaurs, lay over the great plains of Wyoming, Montana, and South Dakota.

By Upper Cretaceous time the widespread and persistent attack of wind and weather had levelled broad areas of land in many parts of the world and the sea had gained one of the greatest victories in its

history. The Arctic ocean and the Gulf of Mexico mingled their waters in a wide belt over west central North America. Smaller detachments from the Pacific and Atlantic oceans took possession of the continental margins. At the same time extensive tracts in South America, Europe, Asia, and Africa surrendered completely to Neptune.

Then, as at the close of the Palæozoic era, the subterranean monarchs took matters into their own hands. Terrific stresses had been heaped upon them with the slow cooling and contraction of the globe. It was time for another readjustment. With a mighty heaving of their backs they arranged themselves for greater comfort. This they attained but only with a profound disruption of the earth's surface. All continents were once more pushed high above the sea, with wrinkling and cracking where the rocks were weak. The trough stretching from Alaska to southern Mexico, wherein the Rocky mountains had been slowly gestating since Cambrian days, was abruptly forced into delivery. A sister trough to the south gave birth simultaneously to the Andes, the longest unbroken mountain chain in the world. To the east the Appalachian mountains, which had been levelled by erosion at the close of the Jurassic period, were gently lifted about fifteen hundred feet with little disturbance of their rocks. Whereas all the known lands were elevated at this time, it is believed by some that certain hypothetical continents foundered into the sea. Volcanoes growled, the air grew

chill, and havoc spread through the ranks of the living.

The great reptiles, apparently exhausted by their successes, vanished with the swamps and the warmth so dear to their lethargic souls. Not only the mammoth lizards of the land, but also the monsters of the sea and the dragons of the air were consigned to eternity. Before they passed, however, they enriched the ranks of the living with two priceless gifts, warm blood and large brains. Birds were given the former but not the latter, and as a result they flew into the future under a handicap that has kept them more ornamental than significant ever since. It was in the mammals that warm blood and large brains united. With energy from their blood and cunning from their brains, they moved to the conquest of a new world. Never as muscular as the reptiles, they triumphed. because they nourished within them the germs of a new force, intelligence. And as we trace their individual destinies we shall see how this force grew stronger until it became the ultimate measure of success.

XIV

HOOFPRINTS

TIME has slipped away since the cataclysm at the end of the Mesozoic era, and that time is known as the Cenozoic, era of recent life. Its entire duration was scarcely longer than that of any one of the remoter periods of the Palæozoic era, yet the Cenozoic has seen the shaping of the modern world. During its six epochs were born the landscapes as well as the creatures of today. With the initial Eocene epoch the sea once more crept over the margins of the continents, bringing the advance guard of an army of modern shellfish. The Mediterranean swelled to a mighty flood which ran amuck over vast lowland tracts in Africa, France, Russia, Siberia, and India; filling basins that buckled later into the Alps, the Urals, the Himalayas, and the Pyrenees. In its waters, limestones of great thickness were built from the skeletons of one-celled animals, rocks which the Egyptians used later in rearing the pyramids. In North America the ocean champed at the edges of the land but failed to gain entrance. Coal swamps lay on the uplifted bottoms of old Cretaceous seaways; rivers and volcanoes cluttered the continent with their débris. The end of the epoch brought a general uplift that drained the interior swamps and moulded the mountains of the Pacific coast to something like their present configuration.

The Oligocene epoch followed with a climate that slowly grew more arid, but the expression on the face of the earth did not change notably until the following Miocene epoch. Intense disturbances then occurred in both old and new regions of unrest. The Pacific coast ranges and the Sierra Nevada came into maturity. The Colorado river began to cut the Grand Canyon in the tilted Colorado plateau. Volcanoes grew profusely throughout western North America. The loftiest mountains of Europe and Asia rose from the sea. Climates became colder and dryer all over the world. When the Pliocene epoch finally arrived, the coast lines and mountains of the earth were much as they are today.

The cold that increased with the world-wide elevation of mountain ranges culminated in the Pleistocene epoch when about eight million square miles of the northern hemisphere were buried under moving ice. Gathering at three centres, one over Labrador, one over what is now the western shore of Hudson Bay, and one over the Canadian Rockies, the ice crawled in all directions, advancing and retreating several times before it finally disappeared. When at last it was gone, great heaps of loose rocks lay over the lands. Rivers were turned from their courses; the Great Lakes and many smaller ones took form in holes gouged by the icy tongues. Similar glaciers made similar history in northern Europe. Many mammals who had enjoyed prosperity in northern lands were killed, others were driven to the tropics.

From twenty to fifty thousand years have passed since the Pleistocene glaciers were at their height. This time is known as the Recent epoch although it was really a continuation of the Pleistocene. The earth is just now emerging from the ice age. Both polar regions and Greenland are still clothed in ice that never melts away ; and all high mountains, even those whose roots are in the equator, bear rivers of ice upon their backs. Hard winters still come to the lands of the north. The age in which we live is an age of transition, both for the lands and for the large-brained two-legged mammals who rule them.

The mammals that came with the Eocene, " dawn time " of the Cenozoic era, were as yet not noticeably " sicklied o'er with the pale cast of thought." Some were large and many were strong, but none were bright. Their teeth were but moderately effective for attack and defence, their feet carried them with no exceptional facility in pursuit and retreat. They were children of slaves and knew not how to be free. Repression, parent of timidity in the old world of obstacles, became grandparent to mediocrity in the new world of opportunity.

The beauty of a tree, however, should be judged by its branches rather than its roots, and the archaic mammals that filled the Eocene world should be appraised for their progeny. They were little distinguished in themselves, they shortly disappeared, but from them sprang one of the largest, most varied, and

eminent families of animals that ever lived. Misfits in the celestial scheme have always been excellent at founding illustrious families, if at nothing else.

Perhaps while dinosaurs were still stalking through tepid marshes of the Cretaceous period, ancestral mammals had found their way to frosty plateaus and upland forests where no reptile would have cared to follow. Warm under their coats of fur, they lived and multiplied in the dreary hinterlands of Siberia, Alaska, and Canada. Although nobody knows this as a fact, it is reasonable to suppose that somewhere the mammals were gathering their forces before the day of liberation. For just as soon as the great reptiles relinquished their spirits to whatever heaven or hell awaited them, the mammals rose quickly to the more tangible emoluments of every earthly paradise. They were too many and too varied to have spawned, as it were, overnight. The formations that hold the bones of the last dinosaurs are directly overlain by strata fat with the remains of mammals.

Like their forbears, the first of the Cenozoic mammals were small, active, and inconspicuous. There was little to distinguish one from another. All had forty-four teeth, long ones in front for cutting, short ones in back for crunching. All moved on flat feet, each foot with five clawed toes. All were directed by small, undeveloped brains. Compared with their descendants not one was intelligent, although when compared with the reptiles many were prodigies of mentality.

Careful scrutiny discloses under their uniformity the beginning of a differentiation that clove the later mammals along lines of special preference as to how life might best be lived. From running on the ground and climbing in the trees, eating what food they could find, the archaic mammals began to radiate toward many diverse habitats and habits. Some took to running over grassy plains and their bodies became dim prophecies of horses and dogs. Others went to the water and foreshadowed the whales and the otters. A few put on weight and suggested the hippopotamus and the elephant. Others burrowed in the earth as do prairie dogs and moles, and still others haunted the tree tops in the fashion of raccoons and monkeys. Although each manner of living impressed a peculiar stamp upon its devotees, none of the archaic mammals rose far towards the mastery of any special environment or technique of existence.

Most living mammals consist of hoofed forms that roam the forests and the plains in search of vegetable food, and clawed meat-eaters that live on the food the others have accumulated. Both varieties were crudely outlined in the mammals of the early Eocene. The bones of the *Condylarthra*, or "knuckle joints," tell of nature's first clumsy experiment with animals who eat grass and run on hoofs. These nondescript creatures with their long tails and heavy limbs were not the best material from which to fashion a horse or a camel. Soon tiring of the task, nature tossed them all into the discard at the close of the epoch.

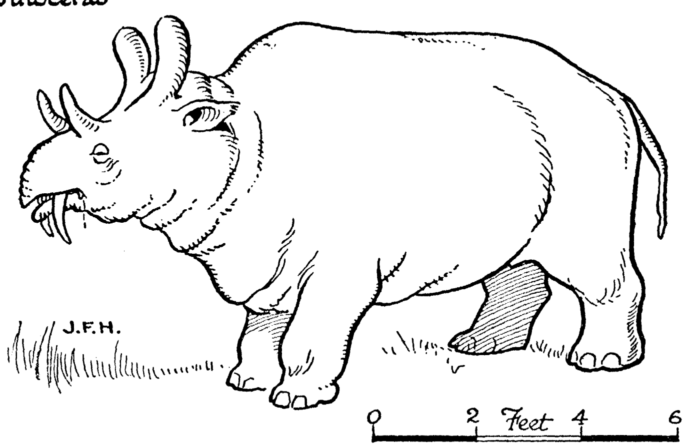
Phenacodus lived at too late a date and was too large and too well developed in certain parts of his anatomy to have been the direct ancestor of the first horses, yet he was the nearest known approach ever made by the archaic mammals to modern hoofed success. He was as large as a small sheep and shared with most other mammals of his day the arched back, the strong limbs, and the flat five-toed feet. Each toe was toughened with a flat nail, the earliest and simplest hoof on record, yet a foot gear far superior to that of any relative. His front teeth were fitted for any kind of food but his back teeth were modelled for the special task of crunching grass. His brain was small, even for his diminutive head, and it led him quickly to the bourne where (let us hope) the stupid rest in peace. Before his bones were discovered, Huxley in England and Cope in America had pictured the probable appearance of the ancestor of hoofed mammals. Although *Phenacodus* fitted the pictures and was esteemed for some time as the founder of a mighty dynasty, he has been dethroned in favour of some even more primitive relative, as yet unknown.

The *Amblypoda*, or "blunt feet," were primitive mammals who vied with each other in stupidity and clumsiness. *Coryphodon* was nearly as large as an ox and as ugly as an hippopotamus. He waddled about in the swamps on short legs and stump-toed feet, grubbing with tusks like a pig. His brain gave him a position well in the front ranks of the most stupid

mammals that ever lived, a distinction for which he soon paid with his life.

The largest and last of the amblypods was *Dinoceras*, who rose on elephantine pillars fully seven feet above the ground. Two curved sabres protruded from his upper jaw and on his head were three pairs of knobs. The front pair above his nose may have carried horns like those of a rhinoceros. The second and third

Dinoceras



pairs, which adorned the skull over the eyes and the ears, where several inches tall and covered with skin like the horns of a giraffe. If nature had striven to be ridiculous she could not have devised a better expression of her mood than the head of *Dinoceras*. The ultimate irony lay in the midget brain, no larger than the brain of a dog and infinitely less complicated: a pitiful rudder for a ship of two tons. The ship hit the inevitable rocks at the end of the Eocene, and with

it the hope of the archaic mammals foundered into oblivion.

Somewhere behind the scenes against which the main events of the early Eocene epoch were depicted, new protagonists awaited their cue. Casual offspring of unknown parents, they had somehow been given potentialities that their ancestors lacked. Vitality was in them that could change their bodies in harmony with a changing environment. The fate of every mammal is shaped with the shaping of three organs: feet, teeth, and brain. The archaic mammals died because they were weak in all these zones of contact with the outside world. But long before they died, even before they reached their culmination, the first of the modern mammals perceived their weakness and surged upon the stage.

Down the radii of the continents from a far polar land they came, in Europe to the fiftieth, in America to the fortieth, parallel—primitive horses, camels, monkeys, dogs, and many another familiar kind of beast. Wave after wave of them washed over the earth until at the close of the Eocene they replaced their archaic relatives, and tasted at long last the full rich sweetness of success.

They who chose hoofs as the vehicle of progress divided into two groups: the one including tapirs, horses, and rhinoceroses wherein an odd number of toes on each foot grew at the expense of the others and eventually supported the entire weight of the body;

the other including camels, pigs, deer, hippopotamuses, giraffes, antelopes, sheep, and oxen, wherein an even number of toes on each foot took over the burden of the body. Hoofs came to both as a result of walking and running on the toes, just as callouses form on the hands of a labourer or on the feet of a runner.

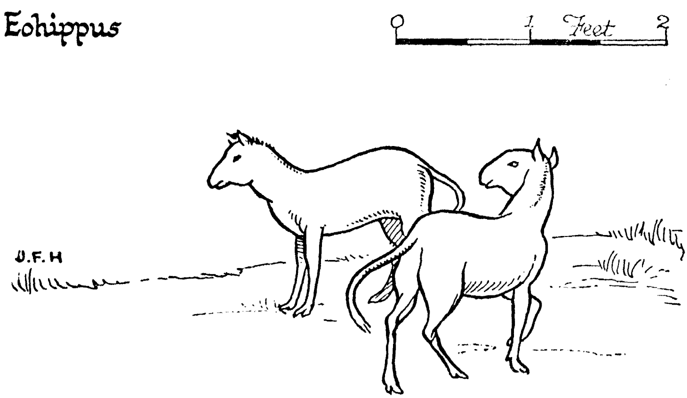
In a world where all creatures are charged to struggle with little understanding towards ends they cannot foresee, it is inevitable that many should drift into the cul-de-sac of biological futility. The ancestors of the horses and the rhinoceroses were brothers who lived the same life in the same environment. Time and the tide of battle swept them apart, but each in his own way won a modicum of victory. Each gave rise to a progeny sufficiently well co-ordinated with the earth to be able to cling to it through all the shifting contingencies of Cenozoic time. Less fortunate but no less gifted than the others was a third brother, the titanothere, whose luck led him into mistakes for which the grim judge exacted the penalty of death before the era was well under way.

Primitive titanotheres with small bodies and slender limbs frisked over the open intermontane plains of North America during the early Eocene. Had they remained agile and comparatively insignificant, their children might be enjoying the pleasures that nature vouchsafed the offspring of other early mammals. They were lured instead by the false security of gigantism. Increase in size is an obvious advantage if strength is proportionately increased. Enemies are

more easily dispatched, mates more quickly convinced, and food more readily obtained. But the larger an animal grows the more food it needs. A very large animal must devote most of his time to his stomach and can live only where food is abundant. His muscles do not gain in proportion to his bulk and he becomes weak, clumsy, slow-moving. The titanotheres grew in size and weight until *Brontotherium* reached a length of fifteen and a height of eight feet. A forking pair of huge horns crowned the nose end of his saddle-shaped head, massive legs supported his unwieldy body. The long journeys between water holes and pastures were irksome, and always when he arrived at a new El Dorado he found the little horses and rhinoceroses there before him. They scattered at his approach but their bellies were fat with the food he sought. Hard times came with the desert; *Brontotherium* and all his kind lay down and died. If there is a place where giants convene after death, the inhabitants may enjoy at least the fellowship that misery loves. Large bodies have ever been the most popular conveyance to the cemetery. They have already carried a great variety of clams, crustaceans, fishes, dinosaurs, and mammals; and within the comfortable cushions of obesity the whales, elephants, hippopotamuses, and gorillas of the modern world are approaching the ghostly convocation of their kind.

Nature dealt less severely with the relatives of the titanotheres. Because the horse is the best known of all four-footed animals, because his history was just

what the proponents of the theory of evolution needed to prove their thesis, he has been paraded *ad nauseam* before the eyes of a long-suffering public. Even in a world where petrol and rubber have replaced oats and hoofs, these eyes may well be weary of the equine display. Unfortunately, horses are still the outstanding example of perfection in one line of biologic endeavour, a perfection just as significant in its way as the perfection of the human brain. Perhaps then



the writer may be forgiven if he takes them once more from their paddock and leads them across a paragraph or two.

Eohippus, "horse of the dawn," graceful and no larger than a cat, entered the forests of Europe and America with the coming of the Cenozoic era. No clue to his ancestry accompanied him, although with the three toes on his hind feet were vestiges of two others, reminders of the prototype mammalian foot of five toes. The front feet bore four toes, but the

ancestral fifth toes had already vanished from the feet and consequently from the record of horses. Primitive though he was, *Eohippus* had begun to develop the gait so peculiar to latter-day horses. The rest of his anatomy was quite undistinguished, broadly similar to that of his nondescript contemporaries. His short simple teeth were more like the teeth of a pig than a horse.

From *Eohippus* to the modern horse stretches a beautiful unbroken chain whose links are extinct horses. Each one lies a little nearer the goal of equine endeavour—the ability to run swiftly in open country and to live on the grassy plants of the plains. In each the body, neck, and head were a little larger and more stream-lined, the brain more complicated, sight and smell more acute. Running on the toes lengthened the feet of these ancient horses and strengthened the joints for long, quick strides. The ankles were raised well above the ground and became the hock joints; the wrists of the front limbs became the "knees." Middle toes grew longer and stronger to support the gaining weight, side toes disappeared. *Mesohippus*, one of the intermediate horses, had three toes on each foot, the middle ones much the largest. The modern horse, with only the middle toes left, carries remnants of two side toes in the splints, long slender bones buried in the skin behind the lower limbs. The other two ancestral toes are gone without a trace. While the limbs were growing longer for running, the teeth grew longer for cropping and chewing grass. The

canine fangs for rending flesh were dropped entirely, leaving only the molars whose sole business was to grind coarse vegetable food. Slowly the horses were changed from simple forest animals who would eat anything to complex prairie animals with a special diet. Because every fundamental step in this metamorphosis is recorded in fossil bones, the horses still deserve a place in the world of ideas even though they have been banished from the world of things. They constitute the supreme evidence for the fact of organic evolution.

Always behind changes of anatomy are changes of habits, and behind changes in habits is the ever-changing world. During the Eocene, climate was moist. Marshes, lakes, and streams lubricated the lands, and forests multiplied with abandon. The Miocene brought cooler and dryer days which removed much of the water and replaced many of the forests with grassy upland prairies. The little forest horses had to eat grass or starve. They had to run fast to escape enemies who could detect them with ease in the open country. The Miocene brought also further expansion of the plains at the expense of the forests, and only those horses who adjusted themselves to the new conditions prospered. Their descendants might still be prospering had not the cold, the poison sting of the tsetse fly, and the hunger of primitive man fallen so heavily upon them during the Pliocene and Pleistocene epochs.

Not all the diminutive odd-toed mammals that

browsed the early Cenozoic forests were horses. Some were rhinoceroses, although the small, defenceless, fleet-footed ancestors of the modern rhinoceros looked more like horses than rhinoceroses. During the Oligocene and Miocene epochs they swarmed over North America in great variety and numbers. Most of them walked on three-toed feet. Unlike the horses who never strayed far from the grass-grown plains, the rhinoceroses tried a variety of habitats. One group followed the horses to pasture but competition was too severe and they forfeited their lives in the attempt to become grazing animals. Another group took to the water, learned to swim and to root in the muck with tusks, but for some reason they did not make a success of it. Others grew large bodies and culminated in *Baluchitherium* of Asia, the largest land mammal ever discovered. He was thirteen feet high, twenty-five feet long, and looked like a gargantuan caricature of a horse.

When the Pleistocene brought polar glaciers as far south as St. Louis, rhinoceroses disappeared from America. Those who lingered on the frozen tundras of Europe and Asia grew long thick fur to temper the wind from the ice fields. Our primitive ancestors knew them well and drew pictures of them on the walls of caves. They are all gone now but their descendants are the modern rhinoceroses of Africa and Asia. These heavy, hairless, thick-skinned, thick-witted pachyderms are all that remain of a great and varied race. Like their relatives, the horses and the

tapirs, they once tasted success on nearly every land; like them they are now backed against a crumbling wall. The heyday for odd-toed ungulates is past, and with the possible exception of the horses, these creatures will probably straggle into the corral of extinction before many more ages have drifted over the earth.

Early in the Eocene epoch a large group of hoofed mammals developed legs whose axes of symmetry passed between the third and fourth toes on each foot. The result was that the central pair of toes tended to increase in size and strength whereas the side toes diminished or disappeared. The camel led this varied band of even-toed mammals just as the horse led the odd-toed group.

The camels of Asia and Africa and the llamas of South America are all that survive of a large family of animals whose original home was western North America. The conditions that brought horses to the grassy plateaus of the Eocene landscape brought camels to the sandier plains. Like horses, the camels grew larger bodies and longer legs with the passage of time, and their ancestral low-crowned browsing teeth were replaced by the high-crowned grazing variety. Their toes decreased from five to two, each pair cushioned in a spongy pad for foothold on the yielding sand. Eventually under the prolongation of desert conditions the ancestors of modern Old World camels acquired humps for the storage of fatty food and water

reservoirs in the walls of the stomach. Eyes and nose moved toward the top of the head to escape the intense light and heat reflected from the ground. The ears filled with hair, the eyes grew long lashes and the nostrils could close against the swirling sand. Sight and smell were sharpened for the discovery of water. In every way the camel became fitted for life on the desert. Unlike the horse he will not be so readily displaced from the wastelands he has chosen to inhabit. Although tractors have partially supplanted him, much desert commerce will continue to move upon his back.

The first camels of the Eocene were no larger than jack-rabbits. They possessed the remnants of two ancient toes, one at each side of the central pair that supported the body. Their teeth were short and simple. In the Oligocene came camels as large as sheep, but with longer necks and legs, more graceful bodies. Their side toes were reduced to splints and their teeth were neither long nor short. Camels very similar to modern llamas appeared in the Miocene and gave rise during the Pliocene to forms much larger than any living descendants. Until that time not one camel had strayed from the homeland of North America, but with the approach of the Pleistocene epoch ambassadors crossed the land bridge of Behring Strait into Asia, and the isthmus of Central America into South America. Like the horses and the rhinoceroses, camels (with one exception) were gone from the continent that had bred them before the last Pleistocene glacier had withdrawn its icy fingers.

Many other odd-toed hoofed mammals followed the same general route to the present. The founders of the deer family appeared in the Oligocene, small undistinguished animals without horns. In the Miocene came larger deer with two- and three-pronged antlers, and in the Pliocene, four-, five-, and eventually many-pronged types. In the growth of its horns a modern deer makes a rapid résumé of the history of antlers. Unlike the horses and the camels, deer are Oriental immigrants to North America.

Pigs, too, followed the well-trodden path to greater size and fewer toes. They are distinguished less for themselves than for certain aberrant relatives of the past. The giant entelodonts of the Oligocene and Miocene epochs had the bulk of a buffalo, the appearance of a pig, and the soul of a wolf. The hippopotamuses are pigs who took to life in the water. Their bodies grew larger and heavier, their front teeth and lips longer and thicker for delving in the mud. The true pigs of the past were all smaller than the living wild boar, and until man debased their modern representatives they constituted as self-respecting and mediocre a family as ever existed.

Thus nature has shaped the fates of all ungulates to the same tiresome pattern, changing the details of individual careers but never the underlying plan. A cow chews her cud and a sow does not, but both had much the same ancestors and history. The monotony of this history is at least that of repeated success. The ungulate anatomy works. Today there are no animal

bodies more effective for the lives they lead, and it is doubtful whether any better ones will be fashioned in the future.

Elephants are among the most primitive and most interesting of all hoofed mammals. They are queer beasts with their long trunks and tusks, their shrewd little eyes, big ears, and high foreheads. But they are also dignified beasts with their alert minds and bodies that only the dinosaurs, baluchitheres, and whales have exceeded in size. Full-grown African elephants are twelve feet tall and weigh from five to seven tons. Their Indian cousins are only slightly smaller.

The body of an elephant is a quaint combination of primitive and advanced characteristics. The soft organs are decidedly old-fashioned, but the skeleton is one of nature's supreme achievements. Unlike most other hoofed mammals, elephants retain the ancestral number and arrangement of the bones in feet and limbs, but these are modified so as to be a perfect support for the colossal body. The feet carry the original five toes as well as small hoofs buried in heavy elastic pads. Limb bones are not only massive but vertical; the " knees " and " elbows " do not make angles as in other four-footed animals. The great head, with tusks that in some cases weigh more than two hundred pounds each, would be an unwieldy burden for a long neck. Nature gave the elephant a short neck and in so doing forsook her general policy of installing long necks with long legs. An elephant

with long legs and a short neck could not reach food and water without the inconvenience of continual stooping. He might have starved on his feet if his nose and upper lip had not been drawn into a long trunk. With this useful appendage, he not only lifts food and water to his mouth, but he carries objects from place to place and tests the breeze for the scent of enemies. His head as well as his neck was shortened to give better leverage to the muscles that move the trunk and its burdens. The front teeth, except the tusks, vanished ; the molars became like steam-rollers to crush coarse grasses, leaves, and twigs.

The brain of an elephant is twice as large as the brain of a man, but of a far simpler type. Compared with the average hoofed mammal, elephants are remarkably intelligent. They can learn to pile logs and, unlike their two-legged fellow workers in the teak yards of India, they will do an allotted task without being watched. They remember friends and never forget enemies. As a rule they are docile in spite of the fact that nearly all are caught wild and tamed to the usages of mankind.

There is no stranger relationship in the living world than that of elephants and those nearly limbless sluggards of the sea, the manatees or seacows. In the past these creatures were much alike, offspring of some undiscovered animal who groped through swamps for a living. The seacows plied more deeply in the water and the elephants climbed to higher ground. All the differences between the two grew out of the

different lives that lay before them when they parted company in the primeval marshlands.

Sixty miles from Cairo, Egypt, in the Libyan Desert west of the Nile, lie the oasis and lake of Fayûm. Prehistoric men lived there and left their crude flint instruments when they died ; there Amenemhat I dug irrigation ditches more than two thousand years before Christ was born. Later both Greeks and Romans built cities there, and the Ptolemies built reservoirs. Today the lake is shrunken and salt, but its history is full and freshened from time to time by new discoveries.

Not least of the inhabitants of Fayûm was *Moeritherium*, first of the elephants. He lived during the Eocene epoch when northern Africa was a garden of tropical trees and a greater river than the Nile joined the Mediterranean where later the oasis touched the desert with life. He was heavy-set, the size of a pig, with two small tusks in his upper jaw. His neck was long, his head long and narrow, and when feeding he easily reached the ground without a trunk.

The Oligocene followers of *Moeritherium* lingered in Egypt. *Paleomastodon* was larger and heavier than his predecessor, more prophetic of later elephants. His neck had begun to shorten, his legs were massive, two tusks protruded from each jaw. On his long narrow face a flexible snout faintly suggested the trunks of his offspring.

Miocene days brought a rich variety of elephants. They spread from Africa to Europe and soon found their way to Asia and North America. As time passed

their bodies grew larger, their necks shorter, their heads taller, their trunks longer, their teeth larger and more complex. Most were of the mastodon or "nipple tooth" variety, whose grinding teeth were not so nearly smooth as those of bona fide elephants, but crested with conical lumps. Some carried four tusks and others only two.

During the Pliocene epoch the elephants roamed between Europe and America over the land bridge of Behring Strait. When the Pleistocene brought ice to many northern lands, elephants grew shaggy coats against the cold. North America was the home of at least one mastodon and three true elephants during this epoch. Among them were the largest elephants on record, with a height of nearly fourteen feet and curved tusks as long as their possessors were tall.

These monstrous beasts are known as mammoths, not for their size but through a curious Tartar belief that their bones belonged to a giant mole, the "mamantu," who died when he came to the light of the earth's surface. Remains of mammoths are abundant in many lands—especially in Siberia, Alaska and north Europe. Every curio shop in Alaska sells fossil ivory, and the fishermen of the North Sea bring up elephant remains in their nets from a region that was dry during the Pleistocene. Neolithic cavemen of Europe scratched pictures of mammoths on ivory taken from the bodies of their models. Several complete specimens have been found frozen in Siberian gravels. Although the animals had died over twenty

thousand years before, their flesh was so well preserved that dogs and wolves ate it with relish. Even the undigested grasses that went to their last meal were recovered and identified.

Today the elephants are gone from America and Europe. Only two of the formerly many species linger in the jungle recesses of India and Africa, and these are rapidly disappearing. Like so many of their hoofed relatives they are survivors from a day that is dead. Some mystery hangs over the general decline of the hoofed cohorts of the Cenozoic era, but vicissitudes of the ice age and depredations of foes may furnish a partial explanation. With every meal they ate, the mammals who lived by tooth and claw spread death among the grass chewers. And eventually there came a creature who killed as no animal had ever killed before. He killed with a new ingenuity not only for food and for fur to cover his naked body, but for hate and for fun. He has already reduced the ranks of nearly all other mammals. For a whim he annihilated the bison, and he continues to murder countless numbers of furred mammals merely because he fancies their skins about his neck, even in the heat of summer. The end of the present century will see him nearly alone in a world of his own making. Only those mammals that his needs or his caprices shall favour will be allowed the pursuit of happiness—within the limits he shall choose to set.

XV

TRAIL OF TERROR

LIVING has ever been a precarious business. Caught between the cruel impersonality of the earth's energies and the ruthless insistence of hunger and love, all creatures are bandied through the whirlpool of existence. Fate is a component of forces which, however definite they may be in reality, are always vague to the creatures through whom they operate. Until greater perception is granted the children of flesh, chance will govern their destinies and the world will be full of mistakes and misery.

Until greater perception dawns, there will be struggle between creatures and their surroundings for foothold in a shifting world ; between creatures and fellows of their own blood for food and mates ; between creatures of different races for any advantage that may be gained. The will to live at any cost on an earth that cares nothing for life will continue to breed conflict within the swarming hordes who obviously can never be wise enough to avoid it. Man alone may hope for peace, for only he has intelligence adequate to the problem, even though as yet he has accomplished little to justify his customary complacency.

In the past there have always been animals who lived by the murder of their fellows. Although never so abundant as their vegetarian victims, they have cut

a trail of terror through time. No sooner had the flesh-eating dinosaurs achieved the quietus they so richly deserved than flesh-eating mammals appeared. Because they were the strongest as well as the brightest of their kind, they won a rapid and easy success—just such a success as others have gained on an earth where beatitude gets the approval but brutality the results.

Creodonts dogged the steps of the archaic hoofed mammals of the Eocene epoch. Their teeth were crudely fitted for cutting flesh, their nailed toes for tearing it. Like their victims they were nondescript prophecies of more specialized offspring. One group had teeth something like those of hyenas, but they probably ate clean flesh more after the manner of cats. Some resembled otters and mink, others dogs and cats. One bear-like species had blunt teeth with which he may have pulled at carrion. Most were fierce and agile, about the size of foxes. Like their vegetarian associates, nearly all died before the close of the epoch.

Just as more progressive hoofed mammals usurped every domain of the archaic vegetarians, so more up-to-date killers replaced the crude carnivores of the Eocene. From remote northlands they swarmed—dogs, bears, raccoons, weasels, civets, hyenas, cats, and many others. With them came teeth and claws perfected for shearing flesh, brains enlarged and complicated for cunning, muscles and limbs modelled for a nicer precision and a greater prowess. They quickly radiated into diverse habitats. Under their

variform bodies a structural unity still holds them together. The incisor and canine teeth of all of them are developed for murder.

Seven families of predatory land mammals were founded before the middle of the Cenozoic era. Of these the dogs remained most like the ancestral creodonts in habit and appearance. The foxes became solitary marauders, the wolves hunted in packs. Before the Pleistocene glaciers arrived, dogs had roamed over their homeland of Europe and had entered North America, South America, and India. More than one hundred and fifty species left their bones to the geological record; over one hundred species escaped to the present.

Very early the bears tired of an all meat diet and took to eating other kinds of food as well. Their teeth grew blunt and have remained so ever since. The raccoons, too, climbed trees and ate fruits and vegetables as well as flesh. Weasels, on the other hand, have always been bloodthirsty. *Megalictis*, a giant weasel from the Miocene, was as large as a bear and an exacting neighbour. The civets and their relatives, the mongooses, trailed their game through the forests of Africa and Asia, and continue to do so today. With them, but several steps behind, the hyenas have skulked, content to face carrion rather than a fight.

The most accomplished of all mammalian killers are the cats. Every muscle, ligament, and bone is moulded for stealth, strength, and poise. Unlike

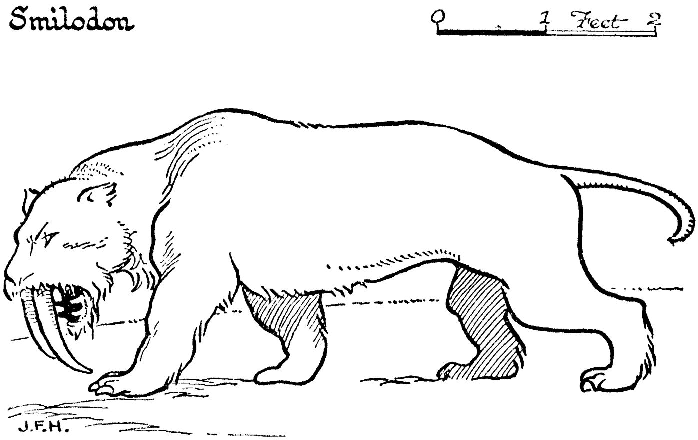
dogs, cats never give honest chase to their prey. They stalk it in silence and leap on it from behind or above. Today the lions, tigers, and leopards of the Old World effectively uphold the black reputation of their family; the puma, the jaguar, and the lynx of the New World are smaller, less fierce, but no less carnal.

Extinct cats are of two kinds: swift, short-toothed enemies of hoofed runners, ancestors of all living cats; and slow, long-toothed stalkers of elephants and other heavy pachyderms, who have sent no offspring to the modern earth. *Dinictis* of the American Oligocene was the founder of his line. Although he belonged to the first group, his teeth showed some of the characteristics later developed by the second. His feet were small, his limbs slender, his claws only meagrely developed. He could overtake any beast that tempted his appetite but he must frequently have failed to hold his prey. In the next epoch, stronger and more modern cats appeared. *Pseudœlurus* was similar to lions and tigers and was undoubtedly their direct ancestor. The first modern lions came in the Pliocene. Southern United States was solidly theirs until the turn of fortune carried them all away.

Early in the history of cats there came a form whose upper canine teeth were long, curved, and edged with notches like a saw. He was the size of a living leopard, but his hind limbs and clawed paws were larger and obviously more powerful. He was the first of the sabre-tooth cats who differed from true cats in martial equipment and tactics. Instead of biting

their prey they held it between vice-like front limbs, stabbing with the daggers in the upper jaw until loss of blood brought death.

Sabre-tooth cats followed the herds of grazing mammals over North America and Europe during the Miocene and Pliocene epochs. Judging from their increase in size and numbers, they found murder an agreeable and profitable business. *Smilodon*, who



terrorized North and South America during the ice age, marked the culmination of a merciless race. His body was one of the deadliest engines of destruction the devil ever invented. The tusks in his upper jaw were ten inches long. His lower jaw dropped straight down so that he could drive the daggers to their hilts into the necks of his victims. Some of the South American sloths spent their phlegmatic lives hanging from trees on curious curved feet. *Smilodon* found them tasty. At the end of the Pleistocene the sloths

were still hanging grotesquely in the trees, their bones rattling in the wind.

Powerful and canny though he was, *Smilodon* discovered the hazards of mortality. Near the western border of the sprawling city of Los Angeles are the La Brea pits, now a park, but once one of the most fatal death traps in the history of life. Here during the Pleistocene, crude oil seeped to the surface from shale rock below and distilled to a sticky asphalt in the heat of the sunshine. Wind covered the oily quicksands with dirt so that animals roaming in the vicinity frequently ran foul of the softer areas. Lured by the cries and struggles of sinking ungulates, the carnivores came to the brink of the death pits. Too hungry for caution they jumped in and added their bodies to those of their quarry. Hundreds of sabre-tooth cats have been dug from this single locality, enough to enrich nearly every museum in the world.

Except for his sabres and his stumpy tail, *Smilodon* was much like living tigers. It is not clear why he did not live on with the tigers. One skull from South America was preserved with the tips of the huge upper tusks locked fast between the smaller teeth of the lower jaw. The animal had starved to death. Some authorities believe that similar fates came to other cats whose sabres had grown beyond utility toward disaster. Many specimens show tusks that had been broken before death. Without their sabres, these cats must have been easy victims for others of their kind.

Perhaps a better explanation of their ultimate disappearance is that the thick-skinned animals on whom they preyed gradually became extinct or better able to protect themselves. The giant sloths are gone; hippopotamuses, rhinoceroses, and elephants are nearly gone. Those who linger do not fear the cats, although lions and tigers prey at times on their young. The sabre-tooths were perhaps just another race that died because it had settled into a special way of living, too rigid to bend to the demands of a changing world.

Not all the killers hunted over the land. Some went to sea and conceived the whales, porpoises, sea-lions, seals and walruses. In every way these mammals paralleled the seagoing reptiles of the preceding era. Their bodies were shaped to the form of a fish, their limbs became flippers for steering and balancing, tails were developed for propulsion. In addition their vitals were buried deep in blubber to keep their blood warm. Special devices were added to feed oxygen to the tissues and to draw off the useless carbon dioxide while the animals were under water. So effective have these devices become that modern whales can endure submergence for two hours with safety if not comfort. The nostrils close automatically and lead directly to the windpipe instead of the throat, so that water may be kept from the lungs. The eyes are built to withstand the pressure of the depths. The ears are well within the head but delicately attuned through resonating membranes to every noise outside.

Early in the Eocene whales had already left the land and had become perfectly fitted for life in the sea. *Protocetus*, with teeth remarkably like those of flesh-eating land mammals, was the first of a line that quickly culminated in the great *Zeuglodon*, fifty to seventy feet long but only five to eight feet wide. Eighty per cent. of his serpentine body was tail. This worthy organ carried him through the water at a rate of thirty miles an hour and through hard times by means of the fat it stored. His neck was short, his front limbs were reduced to small paddles, his hind limbs gone. He was powerful and successful for a time, but the branch that bore him withered and fell from the tree of life before the close of the epoch that saw it sprout.

The ancestors of sperm whales were small marine mammals with shark-like teeth. Over one hundred varieties came into existence with spectacular suddenness during mid-Cenozoic time. Many of their descendants continue to hunt fish in modern seas although man has done his best to discourage them. The whalebone whales were obviously derived from toothed ancestors. They early acquired a penchant for small molluscs, crustaceans, and fishes, and as their size increased they gulped in their prey without bothering to bite it. Their teeth were replaced by an apparatus for straining the diminutive tidbits from the water. Their heads grew larger and larger so that enough food could be captured to nourish their gaining hulks. Their mouths became gaping caverns,

large enough for Jonah and all his friends. In time they gave rise to the largest animals that ever lived. The sulphur-bottom whale is nearly ninety feet long and weighs nearly ninety tons, more than ten times the weight of the largest elephant on record. Only the dinosaur, *Diplodocus*, approached such a length, but he failed to reach even half such a weight.

Although time and the lives they led changed whales into the strangest of mammals, under their blubber are the structures and functions of other mammals. They lost their hair when they took to the water but even today their young occasionally come into the world after the fashion of their remote ancestors, with a coat of fur.

Not all the mammals with sharp teeth and claws used them against their fellows. The rodents early applied their chisel-shaped teeth to wood and nuts. They have always prospered and today they are the most numerous if not the most distinguished of mammals. Beavers, mice, rats, rabbits, squirrels, porcupines, muskrats, and similar creatures are familiar residents of every land. The bats entirely abandoned scratching for a livelihood on land. Membranes spread over their clawed fingers and they chased insects in the air.

The forerunners of sloths, armadillos, and ant-eaters suffered the unhappy combination of tooth degeneration and gigantism. The sloth, *Megatherium*, was as

large as an elephant, with short legs, stumpy tail, and ludicrously exaggerated hind quarters. He clung to the branches of trees with great curved claws, crushing leaves and fruit with weak unenamelled teeth. He was as helpless as a baby. His relative, *Glyptodon*, was a giant armadillo, fifteen feet long and as heavy as a

rhinoceros. His shell guarded him against many vicissitudes of a competitive world. During the Pliocene these quaint creatures strayed from their birthplace in South America to North America. The

sabre-tooth cats and primitive man eventually arranged their demise. Only their less conspicuous descendants were allowed to live on to the present.

The insectivores constitute one of the most interesting groups of animals. They have come to the modern world least altered of all the mammals. Shrews, hedgehogs, moles, and other diffident animals who hide away in underground burrows are all that remain of a formerly significant society. When mammals were radiating into different channels of living during the Cretaceous period, the insectivores gave birth to certain offspring who hunted flesh on the ground and became carnivores; and to certain others who sought fruit in the trees and became monkeys, apes, and eventually men.

When Linnæus hit upon "primate" to distinguish as "first" those animals that include men, he no doubt was thinking more of the glory of man than of man's humble cousins, the monkeys and apes. He was undoubtedly also thinking of man's brain rather than the rest of his body, for excepting that organ, man is as undistinguished a mammal as ever lived. Had horses chosen the "first" animals of the land they would have elected the hoofed mammals; and with some excellent excuses, for many of the hoofed mammals are farther advanced in their special aptitudes than any of the primates. The same is true of many carnivores. Man's glory must be qualified to recognize the fact that much of his anatomy is primitive and consequently inferior. No animal can gainsay the

power of man's brain although many might consider his spirit of dubious excellence.

Lemurs are the most ancient of living primates. Behind their fox-like muzzles are relatively small and primitive brains. They haunt the tree tops as of old, always moving on four feet in the manner of terrestrial quadrupeds. Their long, furry tails are purely ornamental, but their large eyes serve them well in their nocturnal activities. During the early days of the Cenozoic era they abounded in North America and Europe but they are absent from geological records during the latter ages. Quite recently they reappeared in Madagascar where today they constitute half the entire mammalian fauna. The jungles of Asia and Africa also know the " wailing lemurs " of Kipling.

All other monkeys, apes, and men are known as anthropoids. These are flat-footed mammals with five nailed fingers and toes, large and well developed brains. The American monkeys are small, broadnosed chatterers of tropical forests, biologically remote from man. The Old World monkeys are large, narrow-nosed, and a few are enough like man to provoke vigorous denials from those who repudiate even the obvious if it is unpleasant.

The Simiidæ, who sprang from the same ancestors as man and who are placed in a different family from man more for sentimental than biological reasons, include all the tailless apes who walk on their hind limbs. The Oriental gibbons are the smallest of these, only three feet tall but with knuckles that touch the

ground when at night they walk on the land. All day they swing from branch to branch, clearing as much as forty feet in one swing. Their timing, aim, and muscular co-ordination are perfect. They are the world's most accomplished acrobats, offspring of other acrobats who graduated from a school where mistakes were punished by death.

The orang-outangs of Sumatra and Borneo are fat red-haired apes who crawl through the trees with the clumsy care of a man. The African chimpanzees are nearly as tall as a man, but agile in the trees. Their relatives and neighbours, the gorillas, are five feet tall and weigh four hundred pounds. They are so terrible and yet so human in appearance that tradition has given them the soul of a fiend. Carl Akeley, who knew them well, portrayed them as gentle, peace-loving beasts, only too happy to escape contact with their comely, bare-skinned cousins.

Like so many other mammals, the great apes are declining. Life moves ever in cycles. Individuals eat, grow, reproduce, die—and so apparently do races. Man is fortunately little disturbed to see his closest kin sinking toward their doom. Because he belongs to a family that happens to be travelling an ascending curve, because the desire to get somewhere lies deeply rooted in the human heart, he believes in progress. Progress is a word often on the lips of civilized man, but it is a word of numberless meanings. It refers to changes which may seem desirable to some but not to others. The concept of progress is underlain by that other

concept of destination. Man seeks ends for his struggles, hopes, and fears, where he fancies he will find peace. But these are anthropomorphic concepts born of desire. Nature has an entirely different point of view and nature is still the ultimate ruler of her children. In all things which even remotely touch the lives of men she is infinite and timeless. She has imposed a cyclical pattern upon the universe, whereunder all things are charged to go forever but never to arrive. It avails man little to fret. He had much better travel his curve in the spirit of little children on a merry-go-round, who enjoy the ride though it takes them nowhere.

XVI

TALES THAT DEAD MEN TELL

SEVERAL million years ago the light of the Cenozoic era was dawning on the continent of Asia. From the Arctic Circle to the tip of tropical India vast forests luxuriated under a friendly sky. Many a great beast stalked the depths. Safe in the matted branches, numberless bands of tree folk shrieked derision at the snarling enemy below. Here were the ancestors of many long-tailed monkeys and the tailless manlike apes, unconsecrated children of the jungle. Here too was the creature of destiny, alone blessed of all the horde. For nature had dreamed a dream, and had chosen this one to make it real. Bright in the promise of the new day, the ancestor of man swung slowly toward his goal.

Slowly the land rose, the climate grew severe, the trees languished. The simian paradise became a purgatory because the very existence of the tree dwellers was interwoven with the branches of their homes. Asia began to buckle in the middle as the Himalaya mountains were born. The ancestral forests were cut in two. Before the barrier rose to impassable heights, many monkeys and apes escaped to India, where their descendants enjoy life today in ancient comfort and safety. Others lingered too long in the

northland. Slowly the mountains grew, the climate became colder and dryer, the forest shrank. Cut from escape to the south, the bedevilled remnant of the happy horde met death. Some starved with the dwindling of the trees and tropical fruits. Others tried life on the ground. But here were the teeth and claws of bloodthirsty enemies, and many weaklings succumbed. It is not surprising that but one of all the forms survived, a lone victor in an unfair battle. But this was the creature of destiny whom fate had chosen to be the father of humanity.

The forerunner of man came down from the trees reluctantly and only as a last forlorn hope. He had been just a skylarking vegetarian in an easy, friendly world. On the ground his old fruits were missing, food of any kind was scarce. The cold dry climate was an increasing menace to his health and happiness. His teeth were too weak, his claws too dull to protect him from the powerful foes of his new environment. And he lacked the equipment for running away. The whole world was out of joint. His only friend was the latent power of his brain. He must learn to outwit his surroundings or die. He learned because in him was some of the stuff that men are made of.

Through many generations the apelike bodies of his descendants were slowly moulded for life on the ground. Countless individuals, unable to conform to the new demands, perished. But out of the survivors emerged the human body. Arms were no more needed to swing their owners from branch to branch,

so they became shorter. Legs grew longer. Thighs straightened to bear the weight of the body. The great toe became greater, and lay parallel to the others so that the creatures could walk on the soles ràther than the sides of their feet. Erect carriage was slowly acquired. Hands were freed from locomotion to become instruments of the mind. They lifted the burden of defence and food-getting from teeth and jaws. The teeth, no longer a vital necessity, degenerated, so that today the dentist fights a losing battle in the human mouth. The power of the jaws waned. With the growth of intelligence, muzzle and brow ridges grew smaller; brain, skull, and chin grew larger. Gradually the human face took shape.

With hands no longer tied to the branches, the precursors of modern man learned to protect themselves with clubs and stones. But this was not enough. Cold weather continued to creep out of the Arctic. Food and clothing were necessary to carry them through the long winters. They must turn hunters and track the great beasts to their lairs. The men of the dawn did this and more. They made the discovery which Remy de Gourmont called "the most characteristic act of genius of which mankind can boast." They discovered the use of fire, without which further progress would have been impossible. At last, before weapons, clothing, and fire, the barriers, of climate and foe were down. Early men were able to roam in all directions, to improve co-operative living, to invent articulate speech, to sow the seeds of

civilization. Such is the scientific history of the ascent of man. It is largely the product of imagination. No scholar would maintain the truth of its details, for decay has obliterated much of the tangible evidence of the story.

Whatever may be our prejudices, we cannot take man out of the animal kingdom. It is not an insult to the spirit to admit that man is a mammal. Like other mammals he suckles his young and has a backbone, warm blood, hair, separate chest and abdominal cavities. It is rather a defect of the spirit to deny such an obvious truth. Among mammals the position of man is equally clear. He is certainly no close relative of the duck-mole or the kangaroo because he neither lays eggs nor carries his young in an abdominal pouch after birth. But he does belong to the mammalian group whose young are nourished before birth by the placenta. Among these he is only remotely like horses, elephants, cows, cats, beavers, or whales. Whether we like it or not we must admit that he most resembles the apes. His legs, arms, feet, hands, teeth, posture, even his blood and brain, are strikingly apelike.

The similarity of man and ape suggests that both descended from a common ancestor. The rock record of the past goes a long way towards proving it. Although the truth about the progenitors of man is obscured by the mists of time it is not entirely hidden. The bones of extinct men and manlike creatures, though rarer than precious jewels, are eloquent of the

history of humanity. Some people deny the tales these dead men tell. But fossil men cannot lie.

On the island of Java, along the banks of the Solo River, are rocks long known to contain the bones of late Pliocene or early Pleistocene mammals. In 1890 the Dutch government sent Eugene Dubois to explore these deposits. Work continued for several years and large quantities of bones were unearthed. The fragments of a single specimen will be remembered long after its flimsy stuff has crumbled away. For the skeleton is that of the Java ape-man, perhaps the most significant discovery ever made in the rocky tombs of the forgotten.

Skull cap, left thigh bone, and three upper molar teeth were all that had escaped decay. But these are enough to prove the former existence of a creature more like a man than any living ape and more like an ape than any living man. The skull was only two-thirds as large as the skull of modern man. The size of the brain must have been between that of the highest ape and the lowest man. The brows were overhanging, the forehead low and flat. The nearly straight thigh bone tells us that the creature was as large as a man and walked erect. The teeth were more human than apelike. Most authorities agree that the Java ape-man was more human than simian, although perhaps not in the main line of development to the man of the present. Marcellin Boule, the distinguished French palæontologist, and a few others believe him

nothing but a large and special kind of gibbon. Whatever the truth may be, whether he was our granduncle or our grandfather, or just an exalted ape, the Java ape-man breaks down the barrier between ape and man. He is just the sort of creature that should have existed if ape and man share a common ancestor.

Though far below the lowest human of today in all the prized blessings of mankind, the Java ape-man may have ruled supreme in his day. And that day was scarcely more than a million years ago, an almost negligible fraction of geological time. Since then humanity has travelled so far from the apes that the mere mention of a simian origin is disagreeable to many people. But evolution does not usually move at so rapid a pace. Sir Arthur Keith believes the Java ape-man an old fashioned survivor of a former epoch, and that somewhere there existed a contemporaneous but still undiscovered race with more of the characteristics of modern man.

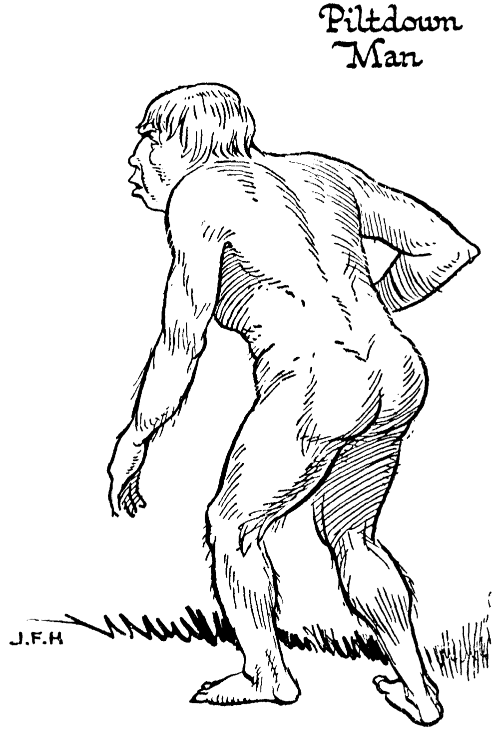
The intelligence of even the earliest human beings is the thorn in the side of the scientist in search of origins. Man, primitive though he was in the early days of the glacial epoch, was not the creature to die a fool's death. The Java ape-man was undoubtedly the victim of drowning. His bones were quickly sealed from the air by the river sediments and preserved from decay. But his friends and relatives escaped such accidental embalming and died on the plains or in the forests where their bones turned back to dust. Death

by drowning before the days of navigation must have been exceedingly rare, and most other deaths robbed time of its record. When early men learned to avoid drowning and to bury their dead in the earth, they learned to destroy the most significant proof of their existence. For bones rot unless tightly sealed from all the cankerous cohorts of decay.

So it happens that the remains of the Java ape-man stand alone in their antiquity. From time to time new discoveries have been made which threatened the isolated glory of the bones from Java. But the new finds proved to be either not so ancient as first thought, or too poorly preserved to tell a clear story. Some of them were found to be not human at all. Recently the bones of *Australopithecus*, a creature resembling a human child, were unearthed from a rather old deposit in Australia. When a complete description of these remains has been made, science may know whether or not it has found a close relative of the creature from whom modern man was descended. The skeleton is undoubtedly not old enough to be the actual ancestor of the men of today, and it is too much like an ape to be classed with even the lowest of men. So, too, in other continents; North America, South America, and Africa have yielded no fossil traces of undoubted men comparable in antiquity with the fragments from Java.

In Europe the bones from Piltdown, England, have long been discussed. The skull is clearly that of a

manlike creature, but farther along the road to true humanity than the Java ape-man. The jaw is apelike, and some authorities believe it the jaw of an ape that resembled the chimpanzee. If the skull and jaw belonged to the same creature, the Piltdown man was



primitive, a true ape-man. He lived, according to some authorities, during the long warm interval between the second and third advances of the Pleistocene glaciers; but according to others, at a much earlier age in the Pliocene epoch. Although they admit him to be one of the oldest of Europeans,

many scientists think he does not deserve the name of "dawn man" which has been given him. They reserve that distinction for the more primitive man of Java.

Perhaps even older than the "dawn man" of England is the man of Heidelberg. Although he bequeathed to the world only his lower jaw and a few fragments of leg and foot, he has the unique distinction of being the one fossil man about whom all authorities agree. He lived near the beginning of the Pleistocene period. The massive, chinless, apelike jaw with its primitive manlike teeth is just what one would expect of this remote creature. He was neither true man nor true ape, but a transition type with the characteristics of both.

On December 2, 1929, W. C. Pei, a young Chinese geologist, discovered the skull of a primitive man in a cave deposit forty miles from Peking. Fragments of the same race had previously been found in the same locality, associated with the bones of sabre-tooth cats and other extinct mammals. As usual, there is much controversy as to the age during which this man existed, estimates placing it variously from four hundred thousand to a million years ago. At the present writing the skull is not entirely freed from the travertine rock in which it was embedded. It is known, however, that the face is missing, but that the brain case is almost entirely preserved. From the appearance of the latter, it is thought that the Peking man was nearer modern man in time and brain

development than were the Java and Piltdown men, but not so near as the cave men of Europe.

Possibly the direct descendants of the Heidelberg man were the men of Neanderthal, the best known of all fossil men. Several specimens from various localities in western Europe tell the story of this widespread race. The mark of the beast was still heavy upon the Neanderthals. They were little more than five feet tall and they walked on short limbs with an apelike stoop. Their skulls were large, heavy brow ridges met across the forehead. Chins retreated, teeth projected, heads were thrust forward. Brains were large but primitive. Despite all this the Neanderthals were men, the first of the Occidental cave dwellers, for they knew the use of fire, and made tools and weapons of fine workmanship. But more than this, they buried their dead with reverence and proved that in their hearts had stirred the first faint feeling that death does not kill all. They ruled over Europe for many thousands of years. About twenty or twenty-five thousand years ago, near the close of the last glaciation, they were driven to their doom by the first of the moderns, the stronger and more intelligent Crô-Magnons. These men were nomadic hunters who camped in the open as well as in caves. They were over six feet tall, broad chested, hardy and capable. Their drawings, paintings, and engravings excelled those of the ancient Egyptians who appeared at a much later date. Eventually the Crô-Magnons were replaced by immigrant races from the East, but

the story of Neolithic humanity belongs to archæology rather than to palæontology.

From the coming of the Crô-Magnons to the present day, the history of man is an unbroken chain. It is unfortunate that the chain is not complete before the coming of these essentially modern men. With the available facts scientists cannot decipher the exact history of mankind. No primitive fossil man thus far discovered can be the direct ancestor of the first modern men. Yet the evidence is conclusive that creatures once lived who were neither apes nor men but both, and that with time these creatures became more human. Their bones all tell the same story of the lowly origin of man.

Today man is far removed from any living ape, for he has gone forward and ape backward. Yet he is also far from the gods. The ego should be pleased to see man the glorious result of infinite striving by apelike ancestors, rather than the degenerate descendant of a god. But nature did not consider our pride when she made us. She cast our bodies in the mould of an animal. No amount of denial will take the beast from our bones. The best we can do is to try to rout him from our spirit.

PART III

XVII

HOBGOBLINS OF THE FLESH

ONE Neolithic morning a skin-clad shaman of France sharpened a crude flint knife. Beside him on a carpet of moss lay a woman, her moans rising above the chatter of a near-by mountain brook. The spirit of evil had long been a prisoner within her, and the man of God was preparing to set it free. Calm in his holy conviction, the priest began his work. Slowly, unheeding the shrieks and writhings of the afflicted woman, he cut through the scalp, cruelly and deeply into the skull. Slowly, ever so slowly, the flint bored and cracked out a large circular piece of bone. Gradually, as the devils escaped through the gaping wound, the woman ceased her struggles; her cries gave way to the low chanting of the priest. A bandage of rough cloth soaked in cold water stemmed the rising hæmorrhage, and completed the gruesome task. The first surgical operation was finished—a human skull had been trepanned. Man had drawn sword against disease.

To the student of fossil creatures, the origin of disease is a fascinating subject for speculation. Was there ever flesh without sickness? If so, when and why did sickness creep in? Back in the dusk of the pre-Cambrian eras, when the earth began to write

history in the rocks, hordes of creatures must have existed. For some reason, perhaps because they had not yet developed hard skeletons, perhaps because of destructive earth movements, there is little trace of them in the rocks. A few, however, have left a dim record of their lives in fossils. The study of these brings out a most significant fact. There was no disease. Bacteria were present but they apparently minded their own business and derived an honest living from lifeless substance. Higher organisms, such as worms and crustaceans disclose none of the defects that mar their descendants.

Our knowledge of those remote times is limited. So far as we know, it was a world happy in its negativity. A world of waste and water. No trees, no grasses, no birds—only the squirming sea slime, and the endless lapping of the waves. No beauty and no eyes to see beauty. No music and no ears to hear music. No Pindar and no pyorrhœa! Here was the Garden of Eden for protoplasm. When did the serpent creep in and failure begin? We do not know, but the serpent brought his poison, and disease crept stealthily into the pores of the living jelly.

In Cambrian days, when the sea mud became the tomb of many creatures, disease was yet unborn. Germs—bacteria—still had a social conscience. Infection was unknown. Although this protoplasmic Eden probably existed longer than man has been on earth, it was but a page in the book of life. The flesh revealed its weakness before the Palæozoic era

had half transpired. Clams and brachiopods were poisoned by certain waters. Their shells thickened or they became dwarfs. Corals succumbed at the slightest chill. Life has always had a stern time with environment.

But this was not disease as disease is conceived today. Disease characteristically is not the struggle of the living with the lifeless, but of the living with the living. A plant attacks an animal or another plant; an animal attacks a plant or another animal. Marauding cells attack law-abiding cells. Such is disease. Maladies began when parasitism began—when one organism found life easier at the expense of another. No doubt the roots of parasitism go down far beneath the surface when it was first discovered. Protoplasm has always sought the easier way.

The shadow of future catastrophe was cast by the Devonian snail who, tired of wrestling for sustenance in a world of uncertainties, found easy living attached to the anal vent of a crinoid. Easy-going creatures have often developed such easy-going relationships. Among present-day organisms can be found many examples of partnership, mild dependence, and intimate co-operation. Barnacles that live on whales, little fishes that spend their lives in the body cavities of sea anemones, intimate intergrowth of alga and fungus to form a lichen. But relationships of this type are always fraught with danger. One member of the firm may take unfair advantage and, living at the expense of its associate, become a thoroughgoing parasite.

Disease probably germinated in this desire of creatures to cast a common lot. Records are faulty, but they clearly show that downright parasitism soon followed such associations. Familiarity bred contempt and advantage-taking. A sponge and an oyster may live together amicably and helpfully, and often do. But the sponge may become unfaithful and bore into the shell of his partner. Living becomes easier that way and sponges are notably unscrupulous.

Before the close of the Palæozoic era, many a partner had cheated. The lower forms were the most lawless. Bacteria, fungi, and moulds added to their earlier love of dead flesh a taste for fresh meat. Worms bored into the bodies and stems of crinoids producing lesions. Bryozoans incrusted brachiopods and strangled life. Parasitism was rife and disease had entered the world.

The mediæval era of life saw the innovation of many modern ailments. During this time the force of growth ran riot, culminating in *Brontosaurus*—thirty-seven tons of mildly living protoplasm. Such a hulk furnished happy hunting grounds for disease. The ancient immunity was slowly undermined. Dinosaurs, mosasaurs, plesiosaurs, crocodiles, turtles, suffered most of the bone ailments of modern man. The bugbear of focal infection was upon the flesh. One Cretaceous horned dinosaur survived a leg abscess capable of holding several litres of pus. A mosasaur with gout stirs the compassion of the investigator. Moodie, to whom we owe most of our knowledge of

Mesozoic diseases, lists fifteen distinct ailments which harassed the reptilian hordes of that day. Tuberculosis, necroses, all sorts of hyperstoses were there. Even rheumatism and pyorrhœa! No one can know the ills that dwelt in the soft parts of extinct animals. Decay has prevented any recording. But it is safe to assume that they were at least as common as the bone diseases.

After the dawn of mammalian supremacy in the Eocene epoch, life was moulded slowly to its present form. With modern bodies came modern diseases. A three-toed horse from South Dakota had a badly swollen jaw which must have been caused by an infection of long duration. Nearly all varieties of modern fractures are seen in the bones of early mammals. Even the insects of that day were strikingly modern, and the tsetse flies of the Colorado Oligocene suggest the possibility of early epidemics, such as the dreaded sleeping sickness of Africa. And finally man came into the world with the curse of disease upon his flesh.

From the earliest traces of ancient man the digger of fossils can detect indications that all was not well with the flesh. The Java ape-man undoubtedly suffered from a severe disease of the thigh. The Piltdown man had some malady which altered the bones of his skull. The original Neanderthal man had a fractured ulna. From one burial mound of Neolithic man in France the bones of one hundred and

twenty men were taken. Over one-third of the skulls were trepanned. Oddly enough, many of the patients had survived the operation and had lived to die from other causes. Stone Age skulls with as many as five great holes are known. All had healed. The devils of headache and insanity were apparently just as persistent in those days. Although the cure prescribed ten thousand years ago has fallen into disrepute, strangely enough, in a few of the back eddies of human life,—in the South Sea Islands, in northern Africa, in the Andean fastness of Peru—the practice lingers.

Trepanation was not the only method used by early man to appease an angry god or to let out an evil spirit. Very early use of the cautery to cure insanity is indicated by skulls seared with boiling oil. In many cases such violent infections followed the operations and left unmistakable marks. Before 20,000 B.C. Palæolithic man had mutilated his body by amputation, usually of the little finger. Tattooing and other forms of scarification were practised as commonly as marcelling and rouging today, and apparently for the same purpose.

Accidents of war and the chase were frequent in the Stone Age. Nearly all types of fractures known today are found among the fossil bones of prehistoric man. Many well healed breaks suggest the development of primitive surgery. On the other hand, many deformities produced in the bones by infected wounds and fractures show to what extent early man must have suffered. All sorts of bone lesions have been found.

Many of these suggest syphilis, but none prove the presence of that scourge. Tuberculosis with many other bone ailments certainly existed among the early Egyptians. Certain mummies present strong evidence of the presence of hardening of the arteries and small-pox. Diseased conditions, whether natural or self-inflicted, prevailed throughout the early history of man.

Wherever the searcher looks among human remains he finds copious proof of the dreadful suffering that followed both disease and its cure. It has always been difficult for a man to die decently of his own private ailments. In those days many patients died from operations otherwise successful.

Coming up into daylight again after our brief descent into the mine of the past we bring with us one bit of ore—one interesting and surprising conclusion. There are no new diseases among the extinct backboned animals. Their bones indicate that they suffered from the maladies of modern animals and men. Species may come and go, but the diseases which rack the body go on, like Tennyson's brook—for ever.

In spite of its importance to the individual, disease has not controlled the ebb and flow of races. Before it gained a firm and lasting hold on the flesh, whole dynasties of plants and animals had come and gone; half the history of life had been written. The trilobite, lowly precursor and distant relative of the lobster, long ruled the seas at a time when the ocean was the only home of life. The period of man's dominance

shrivels into insignificance when compared with the reign of the trilobite. Yet the trilobite tottered and fell. A remarkable immunity from disease blessed this creature throughout his long career. Even the last surviving genus which strove against the inevitable finally passed with flesh untainted. In like manner came and went the thundering saurians of the Mesozoic. Unlike the trilobite they were sadly agitated by disease. Yet science cannot point its finger to a single dinosaur that sickened to premature death. The final disappearance of this great group of land animals is one of the mysteries of evolution.

Though the scientist is baffled before this mystery of vanishing races, he doubts that disease was the principal agent of destruction. For in later times when disease was prevalent, recovery was the rule in race and individual. Triumphant as disease may sometimes seem, it is impotent in the face of that vital force which animates all flesh, that physical immortality which flows from one organism to another throughout time. Extinction must lie somewhere in a failure of this force.

The palæontologist watching the rise and fall of races sees with only actors and setting changed one drama repeated. Thus like the jaded critic he knows the end before the final curtain. He sees that death is the penalty for life. From mole to man, all who live must pay. Rocks are the graveyards of the past, and the student of fossil shells and bones sees the grim

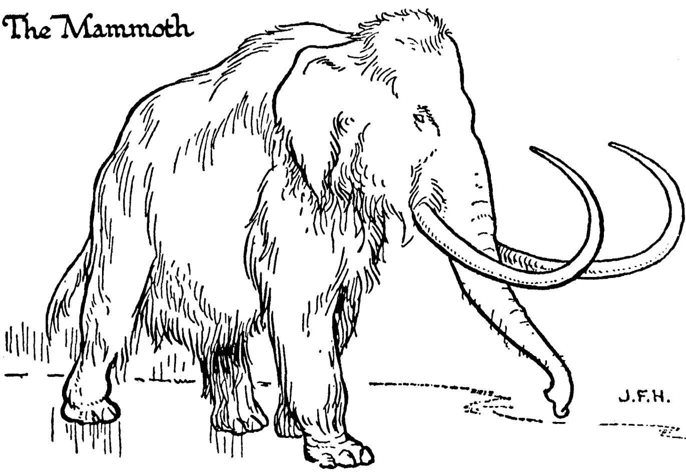
phenomenon in every guise. He sees not only individuals but entire races cut down by the Reaper's blade. Queer creatures have walked the earth who walk no more. Like men who give a part of themselves to their children, some extinct animals acquire a modicum of immortality in living descendants. But many others are hopelessly dead. Like men who leave no children, they have left no offspring species. Their blood has dried for ever. What were the causes that brought them to their doom?

Such changes in climate as those that came with the close of the Palæozoic era must be one cause of the blotting out of races. Cold alone has repeatedly taken a heavy toll. When glacial climates fell upon the earth, whole orders of backboneless marine animals, grown weak and sluggish under a torrid sun, sank into icy graves. A few of the more active ones found salvation in distant seas, far from the deadly currents off the melting glaciers. On land the story has been the same. With the coming of ice sheets, many creatures perished, others were driven to more friendly places. At times a species stood by its guns and won. The Siberian mammoth of the last glacial epoch, nearly alone among the tribe of elephants, gave battle to the blasts from the arctic while relatives fled to greener pastures in the tropics. Unfortunately for heroism, the Siberian mammoth is now extinct from other causes.

Desert climates have often shifted the channels of the life stream. Aridity helped the backboned

animals to free themselves from the water. The Devonian fishes would never have ventured from their pools if a desert sun had not threatened death by suffocation. Waters soured and dried up, many creatures died, but a few learned to breathe air and were saved. From them came the first amphibians, who walked on legs and breathed through lungs for part of their lives.

The Mammoth



With the return of moist conditions the amphibians multiplied. They never lost their love of the water, for they spent their early childhood in it, breathing through gills. This habit was disastrous when the desert came again. Whole tribes of amphibians croaked their version of the swan song. Others escaped and lingered to the present, but with the exception of Mark Twain's jumping frog they were never conspicuously successful. A few adaptable ones

gave rise to the reptiles who breathed air throughout their lives. But even the reptiles were destined to make their offering to the desert, for aridity came once more, reduced the food supply, and starved many sluggards to death. The more resourceful survived and gave rise to the active, warm-blooded birds and mammals. Desert ages, like ice ages, drive the elect over the graves of their less fortunate brethren.

Extremes in moisture conditions, apart from excessive cold or heat, have left a trail of tribal death. Grazing animals have met misery and extinction when increasing moisture replaced their grassy foods with inedible and poisonous plants. Decreasing moisture has been equally effective in removing some of the browsing mammals, by robbing them of the juicy leaves that alone could nourish them.

Underlying the hostile climates that bring suffering and death to the flesh are the periodic convulsions in the rock body of the earth itself. The globe is slowly shrinking, and from time to time the surface is thrown into wrinkles. With each period of wrinkling, the circulation of air and ocean water is changed. Climates in their turn are changed, and the lives of plants and animals. Streams are quickened so that mud and fresh water are borne far into seas that were clear and salt before. Many animals, such as corals, cannot stand the change. They are poisoned by the mud and choked by the freshened water. Some escape but others die. A few remain and fight it out, only to become dwarfs, travesties of their former

selves. And too, on newly made islands, competition grows with the growing hordes and the waning of the food supply. The small stature of Shetland ponies testifies to the rigours of island life. In one place a mountain barrier is raised, closing an area to the rest of the world. Animals increase, foods decrease, and death comes to the weak. In another place a barrier is lowered, allowing a tribe of vigorous foreigners to enter and exterminate the native inhabitants. Near the middle of the reign of the sabre-tooth tigers, a land bridge was established between North and South America. Eager for new hunting grounds, the great beasts crossed from the northern to the southern continent. Even in those days, cats liked the taste of a weakling's blood, and the giant sloths of South America soon became extinct. These and many other examples show how intimate is the relationship between the fate of living creatures and changes in the earth on which they live.

But no change in the environment, however disastrous to individuals, can fully account for the extermination of whole races. Probably a few members would escape to hand on the flickering spark of life. Death comes ultimately from within. Tribes, like men, may make mistakes and pay for them with their lives. Like men, they may grow old and die a natural death.

From the time when living creatures first began to move in different directions, it was inevitable that some should choose paths that lead quickly to the grave.

Over-specialization has ever been the curse of aspiring flesh. Soon after the fishes moved down to the sea from the rivers, they experimented with many body styles. All sorts of bizarre creatures were successful for a time. But they were mistakes and nature eventually buried them. Conservative races were less ornate but more capable of moulding themselves to the demands of a changing environment. Their virtues live today under the scales of descendants.

Later the roof-headed amphibians had their day. But they also paid the penalty for over-specialization. They were too stupid and too sluggish to meet the great crisis when it came. At a time when the drive of life was toward the land they lingered by the water. In time the desert swallowed their pools, and the roof-headed amphibians died.

Reptiles ruled over land, air, and ocean during the Mesozoic era. Among them were the largest and the most rapacious animals that ever roamed over any land. Many were beautifully fitted to their environment and mode of life. But when conditions changed, the proudest representatives of the reptiles were too rigid to meet the new demands. When the swamps were drained and cold weather rolled in at the close of the era, all the dinosaurs gave up the ghost. With them went all the great serpents of the sea and the haughty dragons of the air. Only the simple reptiles were able to carry on to the present.

Mammals, modern protagonists of the life drama, have not come up from the past unscathed. Their

history has clung to the pattern established by their predecessors. The tribes that vanished were not those who remained simple and ready for change, but the ambitious ones who built for permanence in an impermanent environment. The archaic titanotheres with their browsing teeth starved when the forest dwindled and there was nothing to eat but grass. The clumsy hoofed amblypods stumbled into extinction when life became synonymous with speed. Like others before them they succumbed when their world became unfriendly. But they would have survived in spite of vicissitudes if the germ of death had not been growing in their bodies.

Degeneration, like over-specialization, usually heralds the passing of a race. A tribe of Palæozoic snails decided to sacrifice respectability for comfort, and took to living as parasites on the hard-earned flesh of their neighbours. They dwelt in ease for a long time, but finally met the fate they deserved. For when the crucial moment came they were too weak to make the changes that alone could save their lives. Many races have shown marked physical degeneracy before the coming of death. Several species of dinosaurs lost their teeth and then their lives. The toothless turtles, sturgeons, and birds once possessed an impressive armament of teeth. With the possible exception of the birds, the claws of extinction are closing upon them.

When animals become larger than their ancestors and their relatives they are marked for death. Growth

force has repeatedly run amuck in the past. The fable of the frog who tried to puff himself up to the dignity of an ox, only to shatter his body as well as his ambition, is a fact often repeated in the history of living things. A clam is not a colossus and only dies when he tries to become one. Yet many tribes of Palæozoic shellfish, finding life inglorious, tried to become giants. But they burned out with the effort. The massive sauropods of the Mesozoic, sixty to eighty feet long and weighing more than thirty tons, were not only the largest but also the last of their race. Whales, elephants, the hippopotamus, and the gorilla are the largest animals of their kind that ever lived. All are fighting losing battles with death. A living dog is better than a dead lion, but the dogs in nature's menagerie have seldom learned to appreciate themselves.

A faultless indicator of ebbing vitality in a race is the development of spines. Many lines of simple animals, notably among the brachiopods, cephalopods, and trilobites, ended in species highly decorated with spines and pustules. Certain fishes now extinct were living pin cushions. One Carboniferous lizard was rigged like a sailing vessel, but he soon disappeared beyond the horizon and was never seen again. A dinosaur of the Mesozoic was a walking citadel of flesh, entirely covered with armour plates and spines. He could sleep through the attack of any foe. But he was a scion of a race that had spent its vital force, and was soon to sleep for ever. His bones were his only offspring.

If perpetuity were the desideratum of life, then life has persistently chosen the wrong way. A race of corals which attained to a high efficiency for a vigorous life in warm, clear water, perishes when the water becomes cold or muddy. The developed strength of a corpulent, mud-wallowing dinosaur becomes a fatal weakness when the swamps are drained. And this because resourcefulness exhausts itself. Organs and ways of life developed under one environment cannot be changed in a day to fit entirely different conditions. Only a few organisms have remained so simple, so unstriving, so insignificant as to escape the crushing heel of extinction. The lowly shellfish *Lingula* has endured. It dwelt in the slime of the Ordovician sea and is still in the slime of the Pacific ocean. It is content in the slime. There it will stay, eluding death, while others strive for efficiency and perish in attainment.

And what of the future of man? The power of his mind and spirit has placed man on the highest summit of organic evolution. With the characteristic modesty of great rulers, he whispers praises into his own ear. But his point of view is biased and oysters may hold different opinions. After all, man may not be as secure as he thinks he is. His body is weak and may some day be his undoing. Many of his organs have outlived their usefulness. Even his mind has not improved noticeably in two thousand years of intensive cultivation. Perhaps nature is again tiring of her favourite and preparing a new deal. It is not

likely that man himself will give rise to a higher race. A study of the past life shows that advances have always come from the ranks of the undistinguished. A simple, generalized amphibian sired the first reptile, a relatively inconspicuous reptile gave birth to the earliest mammal. Specialized types are held in the rut of their specialty. They have lost their plasticity and cannot make any extreme change. Man conquered the world with his intellect, and no creature can approach him in this capacity. But *Tyrannosaurus* conquered the world with brawn. The pitiful little mammals beneath his feet were likewise beneath his consideration. Yet they took his glory.

Life carries on. Uncertain as are the destinies of individual and race, the spark that fires the flesh will not flicker out. Life will go struggling on with restless vigour until the earth grows very hot or very cold, until she loses her atmosphere or collides with a star. Much can be hoped for the animal who, despite grave weaknesses, rules as no creature has ruled before. It is certain that the diseases which torture him will not eliminate him. Although he is highly specialized, and specialized creatures must die, the play is just beginning and before the final curtain he may learn to thwart the Nemesis of the races. With intelligence in his head, faith in his heart, and a smile on his lips, he may be able to outwit fickle nature herself. If he fails to escape the common fate, it will after all be flesh that fails. And flesh is a considerable nuisance.

XVIII

PATHWAYS OF DESIRE

LIFE carries on. Through all the tortures inflicted by a changing earth, through glacial cold and desert thirst, through flood and famine, the protoplasm has climbed with unabating vigour toward the future. The spark of life, flickering so feebly in the individual, burns with a steady flame in the group. Like spindling faggots in a bundle, the band of living creatures abroad on earth at any given time has possessed a strength immeasurably greater than that of the units composing it. So effective has been the reproductive power of flesh that adversities though many and strong, have been unable to break it. It is not surprising that from the earliest records of self-conscious creatures the generative forces have been the object of wonderment and worship.

When Thoreau remarked that " for him to whom sex is impure, there are no flowers in nature," he spoke as a man who loves nature without qualification. For him, rebel though he was, life and its processes were wonderful and dignified. Because sex makes life possible, it was particularly wonderful and dignified. But when Cabell, three-quarters of a century later, referred to the " cruel and filthy processes of birth ; the unspeakable corruption of death," he voiced the modern impatience with things as they are. We are

beginning to suspect that nature did not arrange the world for the delectation of those few of her offspring who think.

When she invented sexual reproduction as a means of perpetuating her earlier and less ambitious children, she solved a difficult problem with something like ingenuity. The adequacy of the sexual mechanism to the simple needs of simple creatures has been proved through millions of years of effective propagation. When she began to build bodies with a new type of carburettor, but with essentially the same old generator, she missed perfection by a safe margin. She bedevilled the minds and bodies of men because she did not foresee that the love life of a man could not function smoothly through the reproductive mechanism of an oyster. There is an ironic jest in Thoreau's extolling the purity of sex but dying a childless celibate.

There must be a smirk on the old mother's face when she hears men talking of "simple living and high thinking." From the beginning she has denied her children any such combination of activities. In the good old days, notoriously not so good, simplicity at least was possessed by all. Without heart, stomach, or sex organs, living creatures were ideally devoid of many of the obstacles to high thinking. But with the facetious cruelty that has marked her actions through the ages, she refused to stir into her protoplasmic pudding the one indispensable ingredient. When finally she condescended to add intelligence, its rarer savour was all but lost in a weltering goulash.

Consider the amœba who preserves the traditions of the remoter past. He has no stomach, yet he eats and digests food ; neither gills nor lungs, yet he breathes ; no fins, wings, or legs, yet he travels wheresoever he desires ; no brain, yet he makes a good living ; no reproductive organs, yet he breeds more effectively and more copiously than any other creature. With a body invisible to the naked eye, he does almost everything a dinosaur of forty tons could do. In fact he has resources in his very simplicity which have kept his name on the roll long after that of the dinosaur has been erased.

Not knowing what life is, we can think of it only in terms of its manifestations. Even the amœba, simple though he is in the organization of his body, is a seething maelstrom of chemical and physical activity. That is his chief distinction in the world as it is also the chief distinction of higher relatives. The quality of restlessness is so pervasive in the realm of living creatures that it may be thought to mark the outstanding difference between the quick and the dead. Modern physics suggests that this difference is more apparent than real because the same turmoil agitates the atoms of the clod. Perhaps the activity of protoplasm is but a more highly developed and specialized form of an energy common to the whole physical world. Whatever it may be and wheresoever it may have originated, it is and has been the source of all the success, all the failure, all the joy, and all the pain that have for ever been the lot of those who walk in the flesh.

In the living world with its myriad creatures and their myriad functions one process dominates and correlates the energy of all. That process is nutrition. Eating, growing, reproducing, and dying are all that life offers most plants and animals, and these are merely the means, the results, and the failure of nutrition. Nature has played infinite variations on the theme of nutrition. Sex is merely one of these variations.

In the beginning all creatures probably reproduced in the manner of the amœba. All one-celled plants and animals, even a few organisms as highly developed as flat-worms, continue to multiply in the ancient tradition. This method is interesting because it is non-sexual. Before life could gain foothold on a dead earth, living tissue had to solve the problem of acquiring new materials before old materials were used up. When the first bit of living jelly succeeded in growing at the expense of its environment, it had solved half the problems of life.

But successful growth brought the creature to the formidable wall of a universal law of nature, which demands that when a sphere increases in size, its volume must grow as the cube of the radius, but its surface only as the square. Because all organisms gain their living through the surfaces of their bodies, the larger they grow the more difficult it becomes to grow further. When the first creature got round this obstacle by simply dividing into two parts, he had solved the second half of the problems of life.

In this simple solution we see the intimate relationship of growth and reproduction. The latter is merely a more convenient continuation of the former. Reproduction is the necessity if not the privilege of the well-fed. By one of the quaint adaptations for which the intelligence of humanity is noteworthy, the well-fed man escapes the necessity and overlooks the privilege of reproduction. In his devotion to suicide, he embodies a new mood in nature. Until his coming nature had striven to give birth not only to bigger and better, but above all to more and more children.

This double purpose eventually led to difficulties. When the bodies of plants and animals became larger and more complicated, they could no longer reproduce by simple division. Not only the act of division but the reorganization of the parts into complete individuals would consume too much time and energy. Enemies would find easy victims and the purpose of reproduction would be thwarted. Thus it undoubtedly was that the process of budding was invented.

This venerable method of reproduction is still practised by sponges, corals, and many other animals in about the same social stratum. In it we still see the intimacy between growth and reproduction. A portion of a sponge, for example, is able to capture more food than any other part of the animal. It grows away from its parent and its substance is reorganized into a pocket edition of the whole. Eventually the bud forsakes the parent and becomes a sponge in its own right.

Budding was effective enough until animals became still more complicated and their bodies lost some of the vigour of growth. Both division and budding became too expensive. A spider, a fish, or a man cannot afford to present large portions of their bodies to their offspring. They could not replace the forfeited parts. They are not worms who can feed fishes with half their flesh and then blithely regenerate the lost anatomy through that which remains. Nature, like all spendthrifts, practises petty economies. To perpetuate a pair of codfish, she lets a million young ones die, but she will not jeopardize the lives of the parents by exacting more than a handful of eggs and a thimbleful of milt for the coming generation. Such economy, however, is but a whimsicality. In certain worms, butterflies, and fishes, she sacrifices the parents as well as most of the offspring.

Nobody knows just when or where sexual reproduction originated. It is reasonable to believe that when nature began to multiply the cells of her children's bodies and to delegate groups of cells to special purposes such as eating, swimming, and breathing, she included a division of labour for the tasks of reproduction. Even before she had complicated the bodies of plants and animals, she had probably experimented with sex. Certain living one-celled animals perform undoubted sexual functions and perhaps relive those earlier experiments of which no tangible record has been preserved. The significant thing about these functions as exhibited by such a

creature as the slipper animalcule is that they involve neither male nor female elements, and have nothing to do with reproduction. Like the division of an amœba and the budding of a sponge, the sexuality of the slipper animalcule is concerned primarily with growth and not reproduction.

Occasionally two of these little animals embrace mouth to mouth, exchange body fluids, and separate. They go their own ways measurably rejuvenated by the act. With improved appetites and sprightlier bodies they meet the problems of life with new vigour and efficiency. Although they are like as two peas for all any one can tell, the mere act of conjugation gives to each a vital energy that neither possessed before. When we shall be able to understand the nature of the tonic inherent in this simplest of all sexual acts, we shall not only be better able to live in peace with our own sexuality, but we shall, perhaps, be able to frame a definition of life.

The slipper animalcule reproduces by simple division, a process with which his sexual functions have no observable relation. This divorcement of sexual gratification from reproduction may reasonably be considered primitive, a survival of conditions when sex first entered the world. In this ancient practice we see the prototype of companionate marriage. They who claim sweetness and dignity for such a relationship between men and women can rejoice in the fact that it is nearly as old as life itself, and at the same time possess themselves of an argument at least

as forceful as many of the others they use. But throughout most of the evolutionary history of sex, the process was made to serve the needs of the race as well as the needs of the individual. At the same time it ceased to be a function of the entire body and became the special concern of organs with no other concern. At first these organs were no doubt simple, and produced cells all equally capable of growing into new adults. Later two physiologically different cells were developed whose union produced the new individual. Finally the male and female elements were separated and the organs for producing them were housed in different individuals.

Before organisms were endowed with the elaborate mechanism of sexual reproduction, their concern was largely with the environment. Whether they failed or succeeded they met the same problems in the same way. With the coming of sexual reproduction came a profound cleavage in the fundamental traits within each race. Those who were chosen to be females faced life differently from those who were chosen to be males. The former became passive and conservative of their energy, the latter grew more active and spendthrift. There was no escaping such differentiation. Those who were to be mothers just had to devote their energies to the accumulation of nourishment for their unborn young. If they had tried to keep step with their male companions, higher life would have walked into the grave. And with gaining

bodily complexity sex, at first a minor and non-essential quality eventually swallowed nearly the entire living world. Oysters are apparently content that things should be as they are, but more intelligent beings occasionally revolt. That race whose males sometimes write poetry and whose females sometimes vote exhibit in so many different ways the conflicts arising from the mixture of sex and intellect.

Sexual reproduction exacts penalties from all who practise it. It forces upon its victims a loyalty to the purposes of reproduction similar to the loyalty that conscription foists upon members of a drafted army to the purposes of politicians. Until the coming of man the aims of nature were simple—to keep life on earth at any cost. The result may be worth the price, even if the price is the death of a mother oyster and many thousand young. An oyster more or less makes little difference in the world at large, and it would be a decided case of unwarranted anthropomorphism to assume that it would be of much greater concern to the oysters themselves. But intelligence, in so far as it has done anything significant for the race of men, has made of it a race of individualists. The sorriest savage in a jungle hut and the most glorious president of an American university share the same fundamental regard for their respective skins. Let these precious membranes be kept intact and the race may perish from the earth, Andromeda may melt from the heavens if so she desires.

To such creatures as men, the spectacle of life laid

on the altar of sex is a revolting one. It goes on all around us. In some cases her solicitude for the welfare of the race has utterly blinded nature to the needs if not the rights of the individual. The May fly must burst before she can lay her eggs because nature forget to provide a birth opening. The drone who succeeds in mating with the queen of the hive pays for his triumph with his life. All the other drones who fail receive the same reward for their failure. Wherever we look among the higher plants and animals we see the tyranny of sex in one form or another.

We see it in ourselves. Like oysters we are males and females. Like oysters the males are energetic, impetuous, daring, and combative; the females more passive, conservative, timid, and gentle. Like oysters we are lured into the pain of reproduction through the pleasure of sex gratification. Although we may revolt against a system so prodigal with the lives of both parents and children, although we may even question whether the game is worth the candle, we are nevertheless held by the chains of our inheritance. In fact, the erogenous tissues of the human body are more sensitive than those of any other creature. Under all kinds of tactile and mental stimulation these tissues draw us to the sexual act. We are the only creatures who are perennially erotic. The lower animals are only periodically so, yet out of our infinite genius for whitewashing ourselves, we call beastly that which is peculiarly human.

But what is truly beastly is that lower animals can give unconscious allegiance to the mandates of sexuality—to abundant and indiscriminate reproduction followed by chance survival. Most of them are promiscuous though periodic lovers. What little protection any of them give their offspring after birth is as mechanical and instinctive as that given before birth, when the young are still in the eggs or in the bodies of their mothers. Man's consciousness revolts against both uncontrolled breeding and careless rearing. In so far as he has developed the concepts which forbid these processes, he has availed himself of his singular privilege to assist in shaping his own destiny.

On the college fields spring has oiled the wheels of life. Male thrushes are pursuing desired ones over the lawns and up the trunks of trees. Along the walks students are sauntering in pairs, boys and girls toying with thoughts about everything from Plato to football, dancing, and sex. Because modernity has removed many social barriers from between them, because under their badinage is the same instinct that lies under the feathers of the thrushes, they talk chiefly of sex. Many of them graduate, and after untold hours of discussion about careers and ethics, they return to the homes and to the philosophy of their parents. Because the needs of the human heart are the same after education as before, these young people deride Victorian conventions but strive after Victorian values.

The old coat of monogamy is just as tight as ever,

but it is still the approved garment to protect the race against the storms of life. Most of them try to get into it. It is still an outrageous defiance of the sexual mechanism, but it provides a wall behind which the spirit of men and women may be hoped to grow. Behind it, their young, the most helpless on earth, can be nursed and protected to maturity; partly, we know, through instinct; partly, we believe, through willing affection. The weak are harboured with the strong. Throughout, monogamy makes its own law. It is the finest declaration of independence ever made by the mind and spirit of man. Unfortunately it often fails because it coerces but does not change the physical sources of sex. Under its towering structure is a shifting bed of oysters.

Although man has done nothing to change the fundamental biology of his reproduction, he has learned to arrange certain of the consequences to his liking. Thanks to Lister, Pasteur, and their disciples, septicæmia no longer claims half the women at childbirth. Dangerous and revolting birth control by abortion is slowly being replaced by the use of contraceptives. In many ways modern man is opening new evolutionary pathways by eliminating the pain and keeping the pleasure of the reproductive process. Perhaps some day he will be able to gratify his sexual desires for himself and deliver the rest of reproduction to the care of a laboratory technician.

But this may be a sad day for the spirit. Pain, not pleasure, seems to be the real mother of love. Perhaps

we are on the right track in fighting the prodigality of nature. Overbreeding and chance survival are not for intelligent beings. Unfortunately, we may eliminate these without in the least affecting the eroticism which too often antagonizes what we have come to call the higher life. So long as the male human develops over three hundred billion sperm cells during the period of active manhood, he will stand in constant danger of a quarrel with his higher nature.

Perhaps science will sometime discover a harmless way of checking these teeming billions at their source, but the day when the human race can face an alteration of the sexual mechanism may never come. A very old tradition is set against it. At least in loving his pleasures, man is like the other children of nature. Suggest to him on the street that freedom might possibly be bought with a portion of his eroticism, and his answer will be a fair estimate of the distance we have travelled from the oyster bed to Olympus.

But the hope of mankind does not lie in any fundamental alteration of physique. For the present, at least, we must accept our bodies as they have come to us. Hope rises from the latent power of mind and spirit. The current of eroticism will no doubt continue to flow merrily on, but it need not sweep us back to the oyster bed. By consciously shunting part of its flow into channels of deeper living—into love, art, and thought—we may not only escape the tyranny of sexuality but may actually enslave the old master. The front page of any newspaper will prove that this

is not easy. The quiet richness of the lives of a few men proves that it is possible. What some men have learned, others may be taught. The mills of learning grind slowly, but who can say they may not grind exceeding small?

XIX

OLD WINE IN NEW BOTTLES

UNFORTUNATELY sex is not the only heritage that hangs heavily on the shoulders of men. Judging by the cries of the disconsolate, standardization of thought and manners is a blight peculiar to the fair flower of humanity. For almost every house that cleaves to the architectural pattern of a thousand other houses, comes a diatribe against the evils of uniformity. An idea that seldom germinates in the minds of individualistic critics is that such houses, even such diatribes, are the offspring of a venerable but ever prolific tradition. The world in which we live is much the same world for all of us. Despite the varying colour of our skins, we are enough alike to be herded by science into one species. The latitude for variation in the behaviour of any species, whether of men, mice, or angleworms, is decidedly narrow. Even narrower is the range for groups within a species. Because nature has set rigid limits to originality, a million codfish swim with identical tails, a million men live in ugly little houses and believe that when politicians make promises, they intend to keep them.

The hoariest tradition in the world is the tradition of sameness. Not only are members of the same species similar in body and behaviour, but vastly different creatures at vastly separated times have met

the same essential problems in essentially the same way. It does not trouble me especially to know that your body and mine are like as two peas. But it irritates me, as it must irritate you, to realize that in a million ways we also act and think alike. That our joint behaviour is in many regards the behaviour of creatures whom we both despise, is a fact that neither of us cares to face.

Perhaps that is why the fact has been so carefully veiled. So wishful is the thinking of men that even in the books of the scientists, facts that belie a universal urge to originality are somehow kept in the background. The spectre of uniformity stalks through the past and stretches his clammy hands to the present. He is so ugly that men must close their eyes before him. Blithely and blindly poets have sung the myriad " shows and forms " of nature while naturalists have described them. The doctrine of evolution tells a story of plants and animals in endless variety and variation. Always the uniqueness of a natural phenomenon is magnified in the human mind. Looking down the vista of bygone days the student of past life sees the progressive creation of higher and higher organisms. Even though he does not always care to mention it, he also sees certain patterns to which nature has repeatedly shaped not only the bodies but also the behaviour of her children.

He sees monotonous repetition rolling down the ages through innumerable cycles. He sees environment repeatedly the same, and creatures repeatedly

making similar adjustments. He sees that such adjustments are not always the best arrangements for life. Degeneration is at least as prevalent as progress. Repeatedly animals have trodden the same paths to death. The real danger in standardization is that cuckoo notes may be swan songs in disguise.

The blood of man has flowed out of the past, and it is charged with the dross of the past. At one time the reptiles filled every imaginable habitat and lived every imaginable kind of life. Later the mammals, with their more highly organized bodies, repeated everything the reptiles had done before them, with not the vaguest hint of an original adaptation. Their blood flows in our arteries. Because behaviour clings to the traditions of the past, many generations of men, despite the perfection of their brains, can lead lives of sentimentality and credulity, and can murder exactly in the manner of the dinosaurs who clawed each other into the grave over forty million years ago.

The myth that nature never repeats persists in the face of overwhelming evidence to the contrary. It is true that never in the history of life has a defeated organism been resurrected from the dead. A Palæozoic crustacean languishes and dies when his world becomes hostile or when his vitality grows weak with the aging of his race. He and his kind disappear for ever. Similarly organs, such as the digestive mechanism of a tapeworm, when once lost through degeneration, are never regained. In so far as this is true nature does not repeat. But when an amphibian, a lizard,

and a snake, totally unrelated in blood and totally different in body structure, take to digging burrows until through living the same lives they actually grow to resemble each other, nature has certainly repeated.

In the oceans, the oldest home of life, we see animals held in the same slavery to their environment which bound their ancestors for more than one hundred million years. Along the shorelines of the world simple creatures cling to life today as they clung for countless yesterdays. Each day the moon has sucked the ocean from its bed and each day allowed it to settle back again. Each day the animals living on the strand found themselves alternately immersed in water and in air. For the most part they have been children of the sea and in grave danger whenever the sea forsook them. Although a motley company, they have always met the same problems in the same way. They who survived the vicissitudes of the dual environment learned to cling to the bottom when the tide was ebbing, to seal their shells against the drying breath of the land or to burrow into the moist sand when the tide was out. Such creatures were forced to spend half of each day without food, without any effective means of breathing, just passively enduring until the water returned. The result has been that repeatedly through the past entirely dissimilar animals have come to develop identical organs of defence against their environment. Repeatedly they have grown and will continuue to grow to an inflexible pattern, just as

inevitably as house cats will continue to breed house cats and never lions.

In other portions of the ocean, in the wave-churned waters of the high seas, on the quiet bottoms of the abyssal depths, animals have been held in the mould of their environment. Everywhere throughout the past and in the present, we see convergence, standardization. Animals who dwell in the sunlit surface waters of the sea are usually built to a radial pattern. Like the waters in which their lives are immersed they are uniformly colourless and pellucid. They can rise and sink in their medium but they are almost unanimously poor swimmers. Such dissimilar creatures as jellyfishes, molluscs, and the degenerate backboned tunicates conform to this pattern. In the deep sea where all is monotone in the environment, all is monotone in the life that inhabits it. The denizens of this underworld have poorly constructed skeletons, and they collapse when taken out of the terrific pressures of their dwelling place. Most of them are long and eel-like, with sickly hues, with large eyes to catch the meagre light of the depth, with luminous organs to increase it. In these eerie inhabitants of the abyss we see the effect of the most unvarying environment in the world, the most nearly perfect example of standardization in nature.

The strongest animals in the sea have always been those who evolved bodies for rapid locomotion. In the dawn seas of the early Palæozoic era, the straight-shelled cephalopods, remote ancestors of the squid,

were the first racers. Shortly afterwards came the first backboned animals, and able swimmers soon grew among them. Later the marine reptiles, still later the marine birds, and finally such mammals as dolphins, became strong swimmers. No group of animals could be biologically more different, nor geologically more removed from one another than these, yet their bodies were moulded to the same form.

A fish is a perfect adaptation to life in the water. All his ancestors lived and died in the water, and in him we see the flowering of accumulated experience. No ship can depart far from the fundamental architecture of a fish without losing speed or seaworthiness. It is not entirely remarkable that fishes should have attained to perfection. More noteworthy are certain turtles whose flesh was moulded as much on the land as in the water. Although they breathe through lungs they have become such good sailors that they return to shore only to lay their eggs.

More remarkable still were the fish lizards of the Mesozoic era, who came down to the sea from the land, and became so perfectly adapted to the water that they never returned to shore. Far out on the high seas they gave birth to their young alive. They assumed the body form of a shark. Other seagoing reptiles of the past, as well as the living alligators and crocodiles, were moulded in lesser degree toward the form of a fish.

Such birds as the extinct *Ichthyornis*, as well as innumerable living loons, petrels, pelicans, ducks,

gulls, and related forms have been modified in similar fashion. Many mammals, including the water opossum, certain shrews, muskrats, otters, mink; the hippopotamus, but especially seals, whales, and porpoises conform more or less to the same pattern. Behind the porpoise is a long line of land-dwelling ancestors, yet porpoises are as perfectly fitted to life in the sea as the sharks who are their contemporaries, and the ichthyosaurs who lived and died before any water-living mammal was born. And these three—porpoise, shark, and ichthyosaur—so different in ancestry, are so similar in form that an ordinary observer can scarcely distinguish between them.

In all this varied group the same changes took place. Bodies grew spindle-like, necks shortened, tails enlarged, external ears and other surface adornments such as armour, feathers, and hair tended to disappear, limbs became fin-like, and many other organs were altered. Such was and is the road, the only road, to the sea. They who travel it find a relatively easy life. At its end land animals find escape from natural enemies. They no longer need to keep alert because their competitors in the sea are easily outwitted. Food is abundant and gravity tugs less vigorously because of the buoyancy that water gives to their bodies. Their energies turn into growth force. The whales, who left the land for the sea, are among the largest animals that ever lived. Unfortunately dullards and heavyweights are marked for death. No land animal who took to

the sea has ever given birth to a higher animal. Many of them are extinct. Many others are making a last-stand against the inevitable. They are but one illustration of how the evil genius of standardization lures so many different creatures through the same easy life to the same easy death.

On land the story has been much the same. Repeatedly desert climates have fallen on the earth, burning the food and evaporating the drink of animals. Oases were far apart and only those creatures who could travel rapidly could gain the necessities of life. Under such conditions, many different organisms at many different times grew similar organs for rapid locomotion. Many extinct dinosaurs and birds, many living snakes, lizards, ostriches, kangaroos, rabbits, dogs, cats, antelopes, and a host of other animals worshipped above all other gods the god of speed. The ropes of uniformity gathered them all into one corral.

Their bodies were modified for rapid movement through air. Because in running, animals rise upon their toes, feet were turned from the horizontal toward the vertical, and pads were developed to absorb the shock of impact with the ground. Toes, fingers, and unnecessary leg bones were reduced. All limbs grew longer. Certain lizards, dinosaurs, marsupials, and rodents rose upon their hind limbs. Although this happened in eight or more distinct cases, almost identical changes were wrought. Fore-limbs

degenerated, tails grew longer to give counterpoise, necks shortened. Some of these runners have been and still are beautiful machines. But like the sprinters who leave the cinder path for the broker's office, many meet a premature death when the environment changes.

Animals who dig for a living conform to their own peculiar pattern. Snouts, incisor teeth, cheek pouches, and front limbs become specialized for the work of excavation. Tails, eyes, and ears degenerate. Lizards, snakes, owls, swallows, rats, moles, gophers, badgers, and many others have sought their fortune underground. They only succeeded in burying their hopes as well as their bodies in the same hole. The tunnel of a burrowing animal is a one-way street to degradation.

In caves where conditions are unvarying, animals grow to resemble each other. Salamanders, birds, bats, and several other kinds of creatures move in their own peculiar lockstep down the trail to Avernus. Their colour and their sight disappear. Because food is scarce they grow delicate organs of digestion, and stay as best they can their inevitable fate. Like their fellow degenerates at the bottom of the sea they are slender and sickly looking.

In the trees another pattern regulates the lives of animals. Such different creatures as the climbing perch, the tree frog, the chameleon, the woodpecker, the opossum, the tree sloth, and the monkey have moved along the same channels. Their chests,

ribs, shoulders, and hips grew strong; their hands and feet were modified for clinging and climbing. Over thirty times in the history of life climbers were lured by the wider possibilities of the atmosphere. Not all of them attained to true flight, but all of them developed, in so far as they were able, the same mechanism of wings, rudder, keel, and hollow air-filled bones. Like creatures of other environments, they followed a marked road to heaven. When heaven failed of its promise, as it did for the flying dragons of the Mesozoic world, the deluded ones could only die. One of the sad facts of life is that habits become graven in flesh as well as in mind, and flesh cannot change as rapidly as environment. Even sadder is the fact that those mistakes which lead to the death of a race can never be a help to other races, because death cuts the ties of blood, the only adequate cables of communication. Thus it is that the sadistic mother of us all lures her diverse and repeated broods over similar paths to similar ends.

A dinosaur with a twenty-ton body and a two-ounce brain knew enough to eat when he was hungry, to avoid danger, and to reproduce. His nervous organization was on a par with that of a man's stomach which knows enough to digest its food but not itself. Throughout most of the history of life the adaptations of animals have been predominantly physical and unconscious, because such has been the

plan of nature for children who could not disobey. When man came down from the trees, he discovered the use of weapons, clothing, fire, communal living, and language, no doubt with little conscious direction on his part. Only today has he begun to examine his life.

He knows that he, alone among creatures, can alter the environment to suit his needs. He has already opened his mind to new universes. He has chained the power of coal, oil, water, and electricity to his purposes. He has checked disease and lengthened individual life. Quite naturally he has come to believe in his infinite perfectability. Physically, however, he has not advanced beyond the Neolithic-Crô-Magnons of twenty thousand years ago, if indeed he has even maintained their standards. Intellectually he knows much more than the ancients, without having gained any demonstrably greater capacity for knowing. Socially he is repeating in the name of progress some of the blunders of other men before him.

Progress has always been just such a compound of gaining complexity and repetition. The gradual adaptation of a race of fishes to meet the requirements of a special environment is later repeated step by step in the adaptations of a race of seagoing reptiles. The similarity of such phenomena to the pulsations of human development is more than analogy. Although human adaptations are chiefly mental whereas those of lower animals are chiefly physical, the same old

spectre of convergence hovers over both. In the same old standard way, man pours new wine into old bottles, and risks—when he does not reap—the same old death for his mistakes.

Obviously the only escape is through an artificial strengthening of our social virtues. Perhaps some day we shall know enough biology to increase them at the source. At present we can only rely on education to enhance what little originality and decency we possess. Hope lies in a new kind of change, both in ourselves and in our environment. Nature is set against innovation and nature is strong. But if enough men can climb to that highest rung of social evolution, species consciousness, who can foresee what happy lands will appear beyond the horizon of the future?

XX

EVOLUTION IN REVERSE

IT is clear that for his own welfare man must first alter his thinking about nature and himself. He must realize that the gods are not unanimous in the desire to elevate any creature to Olympus. At a time when so many people are taking an emotional interest in evolution, it is not surprising that sophistry should assume the rôle of master of ceremonies. It eases the pain of the tender-minded with a venerated though unworthy evasion. Man was not descended from an ape (perish the thought !) but both came from a common ancestor. Although this statement is well supported by the decree of science, it serves no good purpose when it leads to the bland assumption that our unknown ancestor was an angel. If we could meet him on the street we should undoubtedly run. Further back are the insectivores, remoter forefathers who may possibly console those who like hedgehogs better than apes. Beyond the insectivores are many other ancestors, but they could not conceivably bring comfort to anybody. Even if they could, it would be the false comfort of a head buried in the sand. If we have any respect for our minds we must admit the truth about our bodies.

If man is to profit from the intelligence which has come to him with such difficulty from the slime of the past, he must not close his eyes to the past.

Biological history repeats its mistakes, and the descent to Avernus is easy because the path is well trodden. Man is the only animal with any power to direct his own evolution. Before he can use this power he must learn from the past the reasonable expectations of the future.

A pious delusion of many people who like to moralize on evolution is that all organisms have tended to perfect themselves. Professional evolutionists, themselves, are no doubt partly responsible for this cheery falsehood. It is but human to sugar-coat a pill that is bound to be bitter to many. It is ennobling to think of all nature struggling for higher things. But when most of creation is living in parasitism and degeneracy, when this condition is known to have persisted from very early times, to think of evolution as a physical if not a spiritual yearning toward perfection is clearly to outrage the truth. It is more and worse than this. It is to sing, " God's in His heaven—All's right with the world ! " even while we sink into the abyss which awaits the unaware.

The most casual observer of nature, provided his mind is not made up before he looks, can see that comfort rather than perfection has been and is the goal of all flesh. It is only when organisms must struggle against heavy odds to gain comfort that they succeed in bettering themselves.

Although life in the good old days was not so good, and most organisms went weakly armed to the battle with physical forces, a few were able to sit back and

take it easy. The bacteria remained primitive while æons passed over them and while relatives climbed the heights of attainment. Being small and simple, they were able to adjust themselves to a variety of conditions. Once adjusted they remained small and simple. They have come down to the world today little changed. Many were not content with mere primitiveness, but took to living as parasites in the flesh of their neighbours, and became clearly degenerate.

The bacteria must be credited with success of a sort. They gained their biological desires by desiring little. When plants and animals were separating on dietary grounds, the bacteria were learning to eat everything. Today we find them living on a host of materials, including such gastronomic delicacies as iron, sulphur, and petroleum. Their other adaptations are equally simple and perverted. In remaining primitive and becoming degenerate, bacteria have won a long life if not a noble or exciting one. But they have done merely what all creatures tend to do when they can. It is to their biological credit that they have escaped so long the death penalty that nature likes to inflict upon weaklings.

Before we place the label of degeneracy upon an organism, we must understand what degeneracy is. All flesh has certain limitations, such as, for example, the need of moisture and warmth, the urge to satisfy such primary appetites as hunger and sex. These

are normal idiosyncrasies of the protoplasm. Each specific organism likewise has its perfectly normal specific limitations. It is not to the discredit of man that he cannot fly like a bird. (It is perhaps rather to his discredit that he should try.) It is no failure in birds that they do not reason like men. But when a bird such as the ostrich loses its power of flight, it has degenerated even as a man who has lost his reason.

From the little available evidence it would seem that in the beginning nearly all creatures lived as free and independent lives as were possible under the normal limitations of their flesh. They moved about freely. They earned their livelihood from the dead world and did not steal it from their neighbours. In the parade of organisms through time the student of fossils sees some creatures who preserved their original independence. He sees many others who forfeited it, and became in one way or another degenerate.

Near the very beginning most plants sold their birthright of free locomotion. It was easier to cast anchor and wait for food to drift in, or to be content with what existed in the immediate vicinity, than to sail forth upon the world in aggressive and possibly dangerous search. The vegetable kingdom is still at anchor. The bodies of some plants have improved splendidly with time, yet nobody would compare the finest tree with even the lowest man. In the beginning plants and animals were doubtless indistinguishable. The marked difference in composition, manner

of growth, and response to stimulation did not then exist. They could only have originated after the plants had abandoned locomotion, after they had, in the truest sense of the word, degenerated.

Those animals who chose the easier life of fixity have fared no better than the plants. All corals, bryozoans, cystoids, blastoids, crinoids, as well as certain sponges, graptolites, brachiopods, molluscs, and crustaceans were cut from all hope of high development when they became rooted to the sea floor. When oysters began their career in Carboniferous time they had a respectable position in good middle-class invertebrate society. They kept pace with the best of their kind until they grew lazy and clung to one spot. They have been sitting for so many æons cemented to the bottom of the sea that today they are of no social importance except possibly in a stew. Very young oysters emulate their remote ancestors by swimming actively about for a short time, but only too soon they settle into the lethargy that has degraded their kind.

When marine animals first encased their bodies in limy walls, they gained a great advantage over the physical forces of their environment. No more significant advance in organic evolution was ever made. But success does not always succeed. The shells of many invertebrates became so ponderous that the animals within grew phlegmatic. Oysters are not the only sad spectacle that greets the eyes of the palæontologist. In fact, the history of most backboneless

animals is a story of decadence inside a shell. Squids, lobsters, crabs, shrimps, insects, whose shells have remained thin or have tended to disappear, and whose flesh has kept active, are decidedly the exceptions in invertebrate evolution.

The clam who buries himself in out-of-the-way places and lives his life in calm aloofness is a degenerate but not a rascal. He sits in his own corner of the world and travels his own road to futility without inflicting his habits or his philosophy upon his neighbours. But it is only a step from an easy honest living to an easy dishonest living. Although records are meagre, they show that parasitic degeneration begins when organisms lose their power of locomotion. Partnerships are formed for mutual advantage. Some of these relations work out for the good of all concerned; most end in parasitism. As life unfolded through the ages, parasitism grew until today the ignoble spectacle of one creature living at the expense of another greets us everywhere.

Although the nature of parasitism offends our sensibilities, there is no doubt that it serves a useful purpose in checking the multiplication of prolific organisms. Darwin calculated that a single pair of elephants, the slowest breeding mammals on earth, were capable of nineteen million descendants in seven hundred and fifty years. The imagination staggers before the potentiality in a pair of rabbits. It is easy to see that the space and food supply of the earth's surface would rapidly be exhausted if nature's prodigal

fecundity were not checked. Certain parasites must be thanked as one of the instruments that save the earth from suffocation under the bodies of her offspring.

However valuable some parasites may be in the economy of nature, however little the others may wrong their hosts, they are always their own enemies. Excepting the one-celled germs, all parasites have fallen from the position held by their free living ancestors and relatives. Some parasites are of high descent and in them we see the best example of backward evolution. It cannot be denied that parasitism is often a successful adaptation from the point of view of the parasite. But that point of view is an uninspired one. The tapeworm, most successful of parasites, has lost his locomotion and his sense organs. Through absorbing food already digested in the alimentary canal of his victim, he has lost his digestive organs. He has degenerated sexually and is truly a worm among worms. He has not only lost the bodily excellencies he once possessed, but also the prospect of ever regaining them; for biological honour once sacrificed is never regained. Yet he has won the comfort and security he wanted, and has merely carried to an extreme a tendency which is in us all.

The cause of variation in plants and animals is the ultimate explanation of evolution. Biologists are so busy excavating their haystack for this elusive

needle that they have devoted little attention to the striking fact that many organisms have failed to vary and hence to evolve, either progressively or regressively. There are many creatures who sit on the biological ladder, too sluggish to climb, too vigorous to fall. Such stagnant types have been so abundant thay they can hardly be considered exceptions to nature's plan. No great subdivision of invertebrate animals has been without its sluggard genera. Fifteen per cent. or more of the genera in several subdivisions lived practically unchanged through two or more geological periods. Whatever may be the cause of such persistence, its occurrence is proof enough that the universal tendency to perfection is a myth.

Although stagnation and even degeneracy have fallen upon races as highly developed as amphibians and reptiles, the most conspicuous as well as the most numerous cases of racial persistence are found among the lower invertebrates. The one-celled Foraminifera which form our chalk deposits, as well as corals, brachiopods, and molluscs contain members who have marked time for æons. Such animals may have been the hubs from which shorter-lived races radiated. They may have been just the lingering remnants of stocks that had passed their peaks. In either case they were left behind by more rapidly evolving descendants or relatives.

However vague may be the inner biological factors underlying evolution, the outer environmental factors are clear. Unless organisms are kicked into activity

by a hostile environment they get nowhere. Since no living creature has ever enjoyed being kicked, there has been in the past, as there certainly is now, a universal attempt to avoid it. That is why there are animals living in the surface waters and the abyssal depths of the oceans. In such places climatic and geologic conditions have been most unchanging. Here many organisms found a haven where they could live long lives of dullness. There was nothing in their surroundings to stimulate progress, so there was no progress. Meanwhile more vigorous relatives faced a harder life in the shore waters of the oceans, in lakes, rivers, and on the land. These were driven to change or to extinction, but they were seldom abandoned to stagnation.

So close is the relationship between the evolution of a given race and the physical history of the earth, that the palæontologist sees in geologic change the deity who pulls the strings. Wave after wave of organisms have piled upon the shores of time, each wave a little larger than its forerunner, until at last humanity came. But when the winds of geologic change stopped blowing for a time, when the inorganic world became relatively quiet, then the living world grew quiet and stationary too.

No great evolutionary advance has ever come under an easy environment. When continents are rising or falling, and seas are leaving or entering the lands ; when rivers and lakes are drying up ; when mountain ranges are being built and climates are changed ; when

gardens become deserts and glaciers desolate the tropics—these are the times when creatures better themselves. It was only when continental uplift quickened streams that active animals with backbones arose from the invertebrates. It was not until aridity had dried up their pools that fishes grew lungs and legs for life on land. Not until the forest homes of our arboreal ancestors had dwindled in the cold, did man come into existence. Without such periodic stirrings from without, all plants and animals would settle placidly into lives of stagnation and degeneracy.

This tendency to stagnation and degeneracy is in no way better shown than by the races that have failed to progress in spite of extreme changes in climate and physiography. Some creatures have found isolation near the very thick of the battle. Types that burrow in the ground escape many of the vicissitudes of a stern environment and a cut-throat competition. They live long and undistinguished lives. Some burrowing brachiopods have come from the seashores of the remote Ordovician period to those of today, almost unchanged. Their vitality seems just as great now as it ever was, and they will probably pass over the horizon of the future as they have risen from the past, immortal and insignificant.

Certain individual peculiarities have favoured the stagnation of some creatures. Attached degenerates like corals live longer than many of their more deserving neighbours. Small, inconspicuous animals live longer and evolve more slowly than large, impressive

ones. Reptiles had their day when they blossomed into the largest land animals that ever lived. But after the sun had set and risen again the dinosaurs were gone, and only inconsequential snakes, turtles, and lizards were left to carry forward the reptilian banner. Many living birds and mammals have slipped through the mills of time because of their small size. The kiwi, flightless bird of New Zealand, is the smallest of the giant Moa tribe, and the only one alive today. The shrew is not impressive but he has lived longer than many haughty relatives. The sturgeon is one of the most prolific breeders among fishes. This fact is perhaps the chief reason why the sturgeon is still on earth long after all his immediate relatives have become extinct. The pearly nautilus is the lone survivor of a great race. He has passed through several geological periods almost unchanged, yet he tears the nets of fishermen and displays in every way such remarkable vitality that no one can doubt the reason for his racial longevity. The capulid snails are the sparrows of the sea. Since Carboniferous time they have been living on the excrement of their neighbours. They have been granted a long life, though a stagnant and ignoble one, for their lack of fastidiousness.

Nature is cruel. With supreme irony she allows many of her degenerates and sluggards to live on indefinitely, and rewards her more ambitious offspring with an early death. A universal trait of the flesh is that it builds only for the present. If the future

brings new conditions, the very organisms that succeeded most admirably may perish most miserably. The past is strewn with the bones of creatures who became so rigidly adapted to one set of conditions that they could not change to meet the demands of new conditions. Nature flips the coin with a " Heads I win—tails you lose." She offers her children stagnation and degeneracy on the one hand, or over-specialization and extinction on the other.

It seldom fails that progressive races become better and better adapted to a particular environment and mode of life, until they are so rigid that change is impossible. Early Cenozoic time was the heyday for browsing mammals. They had met the requirements of their environment perfectly. But when their forests shrank and they were forced to eat grass or die, they died. Their teeth had become so specialized for browsing that they could not learn to graze. The forest horse, *Hypohippus*, was a more progressive animal than his contemporary, *Merychippus*, but *Hypohippus* was a browser and became extinct, while the more primitive *Merychippus* gave rise to grazing horses whose blood still flows in the veins of modern horses. It is an almost universal law of nature that creatures become set in their ways, whatever they may be. This is merely a response to the universal urge to be comfortable which dominates the lazy and the active alike.

Evolution has trodden its many pathways undirected by the creatures in which it moves. Even man has

reached his present condition with little conscious direction on his part. Since most of us are willing to swallow the religion of our parents, the government of our rascals, even the morality of a money-making age, it would seem that we are perfectly normal animals going willingly where we are driven. Yet with all our conformity (or standardized unconformity, when that is fashionable) we have an innate faith that we are masters of our destinies.

We have developed far enough to know that this is at least partly true. We need not be blind slaves to nature. Despite the ebullitions of physical culturists, our bodies are weakening; yet we are side-stepping the racial death that would certainly come to less intelligent animals for similar weaknesses. Many of our organs are useless antiques, but when the appendix, for example, threatens our lives, the surgeon cuts it out. A sound set of teeth is nearly as rare as a coat of fur, but the dentist reinforces our mouths, and the clothier conserves our bodily warmth. Our hands have lost their glory, but they can still push buttons. We are losing our acuteness of vision and hearing, but as long as oculists and ear specialists can assist most of us in distinguishing red from green traffic signals and in hearing the whistle of a locomotive, the race will not perish from these defects. Our sense of smell is almost gone, yet this is a defect not without its compensating advantages. Our upright carriage makes childbirth increasingly difficult, but before our life stream is dammed at its source we

shall probably discover some way of removing gestation to the laboratory.

Although we are not the men we used to be, our physical shortcomings will probably not exterminate us in the immediate geologic future. Our bodies will hold together, with a little help, for a long time. With his brain man has already won exemption from some of nature's sternest laws. Nature decrees that the unfit shall die. Man rules that when the unfit are human, they shall be placed in asylums. Nature demands complete control over her children. Man defiantly invents schools, hospitals, churches, and consciously strengthens himself.

How far man can use his intelligence to shape his own life, nobody knows. Nor is the goal to be striven after any clearer than the means by which it may be reached. Unfortunately he is swayed by brute passions. A decade ago it was the lust to kill; today, if novelists reflect current trends, it is a morbid devotion to the urge to reproduce. Such divagations from the course his intellect points out may be but minor victories for nature, yet they suggest how easily even the mind and spirit of man can slip into reverse gear. If he is to escape the clutch of backward evolution, he must first know nature for what she is. This may mean the destruction of some of his dearest delusions and a less devout worshipping of their creator. But it is the only way of clearing the path to mental and emotional fulfilment.

XXI

HIGHWAY TO THE MOON

MAN, standing at the verge of a vast and uncharted future, turns to the past for help. Perspective should yield a pattern and a prophecy. And if there is any hope for the casuals who drift along the highways of time, it should be visible somewhere in the scene. But the past is a desert graveyard and man does not readily discern the hope he seeks. Dead bones and dead ambitions stretch cold and chill and countless over the ground. Futility, like a foul bird, hovers in the air.

The future has ever been the suckling of the past, and creatures have ever inherited the framework of their fate from their parents. Self-conscious man, viewing the dismal panorama, sees in himself the same inadequacy that bore upon those who went before, the inadequacy of race as well as individual to grapple the grim legions of decay. The repeated cycles of growth and dissipation of vital energy, the cruel prodigality of reproduction, the unyielding grip of custom, the downward drag of retrogressive forces are the poisoned gifts of the past to the present, of beast to man.

Yet nature, lover of paradox, allows the delicate flower of rational hope to bloom, not where earth is warm and life throbs passionately, but where failure

and death have laid low the land. For out of the discouragement of the past, intelligence has somehow emerged. Rising in ages too distant to be seen with clearness, it has broken a trail to the present, a trail that has grown not only longer, but also straighter and wider. Today it is a well-marked road that has never been known to lead a traveller into disaster. No one can say where it will ultimately go, but man, the hopeful animal, believes that at its end things as they are will have become as they ought to be. For man the highway of intelligence leads to the moon.

Although we still print hearts on valentines, we no longer believe this worthy organ the source of affections. Nor do liver and spleen, except in the clichés of language, continue to breed human emotions. Since the time of Vesalius, those qualities that form the personality of man—instinct, reason, memory, imagination, emotion—have been known to be children of the nervous system. Through four hundred years a mountain of evidence has accumulated to show that all the qualities we esteem in man, the qualities that make life tolerable, are functions of the nervous system. The poetry of a soul breathed into man by God has become the science of an evolving cerebral cortex. Fortunately in this case the facts do not destroy the poetry. They do not alter the quality of the human soul. By giving it a material base and a history, they add to it the glory of a growing triumph through the past and the promise of improvement in the future.

Long before a brain found lodging in the head of any animal, nerves threaded the flesh of simple creatures and guided them on their way. Long before true nervous tissues became the wires of communication between animals and their world, muscles received stimulation directly from the environment. And long before this, before the cells in the animal body were multiplied, simple protozoans must have held in their tiny bodies the essence of nervous activity.

No animal could ever have lived without some means of distinguishing good from bad in the outside world, and some ability to regulate his movements accordingly. Perhaps in the beginning all life resembled the modern one-celled *Paramecium* whose microscopic droplet of living jelly can move toward food and away from danger. Without the slightest observable trace of nerve tissue, this creature can vary his reactions to meet exigencies imposed by a fickle environment. Every day of his life *Paramecium* exercises a crude sort of choice, and by so doing, suggests the probable foundations upon which the perception of higher creatures was erected.

Sponges, lowest of living many-celled animals, epitomize the next stage in the evolution of a nervous system. Although in death a few are devoted to the pores of the human body, in life they are only concerned with the pores of their own bodies. Opening and closing these pores and thus controlling the food-freighted currents of water, has filled the life of every sponge since the Algonkian era. The control of each

pore is lodged in simple muscle cells that receive stimulation directly from the outside world and are nowise nervously connected with the muscles that control the flow of water through neighbouring pores. Because sponges have never grown beyond this primitive adjustment to surroundings, they have remained the most sluggish among the multicellular animals, one of the best examples of stagnation in nature. But there is compensation for everything. If a fish is foolish enough to bite off the top of a sponge, the fish undoubtedly suffers indigestion, but the sponge proceeds as placidly as before, insensate to both insult and injury.

Nature, always tiring of simplicity, early built into the bodies of corals and their kin the rudiments of a true nervous system. Touch any part of the sac-like body of coral polyp and the animal will quickly contract. A network of simple nerve fibres evenly distributed just beneath the surface carries outside stimulation to the inner muscles of the body. Corals, like sponges, can undergo with equanimity the loss of a considerable portion of anatomy. Every part of the body is independent of every other part because each part possesses a neuromuscular mechanism adequate to its needs.

Very early in the history of life a variety of animals grew tired of watchful waiting and began to grope impatiently for food. They poked their brainless heads into a world full of bumps. It was not sufficient that they possess a simple nervous system diffused

impartially throughout their bodies. That part which took the lead into the unknown needed something more. Perhaps it was from this need that the first organ resembling a brain was born.

Molluscs, worms, and arthropods grew small bunches of nerve cells in the fore parts of their bodies, from which chains of simpler nerve tissue dragged aft. By this means, sensations received through the skin were carried to the various muscles of the body. Because head and mouth were most frequently in contact with the world, these parts became sensitized above the rest of the body. An eternity of time and an infinity of change lie between these creatures and man, yet the first worm that crawled over the mud of a pre-Cambrian shore carried with him the prophecy of human personality.

Man, always appreciative of his own good qualities, likes to think of his brain as a unique gift from heaven. It is, to be sure, the only organ in the human body not easily excelled by similar organs in a host of other mammals. Although it is the most intricate structure in the entire animal kingdom, it is none the less the offspring of brains that saw service for millions of years in the heads of humble creatures. Man's brain is no more original than most of the thoughts that spring from it.

The crude models of a central nervous system preserved in the fossils of some of the earliest back-boneless animals were built to a pattern that nature

has never since forsaken. Just as the first automobile contained rudiments of the modern limousine, so the first nervous systems suggested the last. In the early fishes the brain and spinal cord of man were clearly foreshadowed. A fossil ostracoderm from Silurian rocks of Germany preserves the oldest record of a true brain. As in man, the brain of this primitive fish was an enlargement at the front end of the spinal cord, terminating in a tube whose purpose was to register the sensations of smell. Just behind and corresponding to the human cerebrum was an enlargement of the ostracoderm brain. Behind this was the still larger heart-shaped mid-brain, connecting as does the similar structure in man with the organs of sight and possibly of hearing. The hind-brain was club-shaped, expanded in front, but lacked the high differentiation of the human cerebellum.

From that day to this, brains have remained ever the same under a gaining complication in the details of structure. The fossil brain of one of the ancestors of the sturgeon was cracked out of a nodule from a lower Carboniferous rock in central Kentucky. It proved that fishes had gained keen vision and sharp hearing since the days of the ostracoderms, qualities no doubt essential in a fish, since without them the ostracoderms had died. The ability to reason had obviously not yet appeared, nor indeed did it ever become an outstanding charm among wearers of the fin and scale.

The fossil record of the lower four-footed land

animals is unsatisfactory because the brains of these creatures are imbedded in fat, and the form is nearly always destroyed by death. Enough reptilian brains have been preserved, however, to prove the gradual perfection of this organ. On land the sense of smell is a vital necessity. The oldest specimen of a reptilian brain was found in Permian rocks, and it showed a decided increase in the size and complexity of the olfactory lobes over those of fishes. On land locomotion is more difficult than in water. Early Mesozoic reptiles exhibited a marked growth in the cerebellum, the portion of the brain concerned with the co-ordination of bodily movements.

The earliest mammalian brains were reptilian in character. They were small and the cerebellum was larger than the cerebrum. Soon, however, when competition made intelligence both respectable and valuable, the cerebrum (organ of thought) became fully as prominent as the cerebellum. After the Eocene epoch the mammalian brain increased in size and complexity. Convolutions increased, the cerebrum outdid the cerebellum. Almost without exception, those mammals who survived to the present had larger and more complicated brains than the average of their companions, whereas those who failed had smaller and simpler brains. Mentality had at last become the wielder of destiny.

Thus flying rapidly up the ages we arrive at the brain of man. It is the perfection of all that was good in its predecessors. It is not likely that earth

will ever see a better brain. If improvement is to bless the lot of man, it will come not through a gain in the size and complexity of his brain, but through an extension of its use.

Intelligence, that rarest distillation of the perfected brain, is a will-o'-the-wisp that eludes the barriers of definition. No scientist is wise enough to explain how it is made, nor certain when it first appeared. The successive stages in the evolution of the brain are crystallized in the heads of living animals from fish to man, and it is to them we must turn for some suggestion as to the history of the brain's functions.

It becomes clear at once that the business of most brains is not to manufacture intelligence. That quick adjustment to new conditions characteristic of human mentality is rarely displayed by any other animal. Yet because we like to think in terms of ourselves and because we are congenitally sentimental, we see human intelligence in all sorts of innocent creatures.

A man catches a fly in a room dark except for a narrow rectangle of light allowed to enter through a partly opened window. The insect beats and buzzes against the walls of his prison, and when the hand is undoubled sails to the open window and escapes. Judging from printed interpretations of a multitude of similar incidents the average man would say that the fly realized his danger, and when the

opportunity came, quickly and wilfully chose the only correct avenue of escape.

Unfortunately this proof of intelligence in flies suffers if a flame is made the only bright spot in the room. For the poor fly is so built that he must go toward the light whether it frees him or fries him. Like the behaviour of the fly, that of almost all other animals is largely if not entirely outside the range of voluntary control, regardless of the fact that many animal reactions are beneficial.

Our sentimentality is magnanimous. We often see in animals not only the intellect of man but also his feelings. Every year the bookstalls display a crop of literature dealing with the human side of birds, beasts, and even flowers. The books of the Nimrods are noteworthy. Human choice and emotion are attributed to animals who in most cases merely follow blindly the frozen paths of age-old instinct. The myth of the bravery of big game has grown from a double root: the habit of seeing everything in our own image, and the human desire to conquer in fair fight. It is not sporting to murder a cow in a pasture; so the hunter who murders an antlered cow of the woods builds a myth which not only enables him to pull the trigger but even to boast of it afterwards. Although the charge of a wounded animal may be only the misguided instinctive attempt of a weak-visioned creature to escape, the hunter invariably dresses the action in terms of human virtue or vice.

Controlled laboratory experiments in nearly all cases lead to the conclusion that animal behaviour falls in one of the three great groups of reactions known as tropisms, reflexes, and instincts. Such reactions occur repeatedly and cannot be altered by the individual even in the face of certain death. An earthworm rises to the surface of the ground after a rain and replenishes the liquors of his body so that he may continue to burrow along the dark path of his destiny. For millions of years earthworms have risen to the rain. This behaviour is probably only an accidental variation that survived because it was useful.

Once acquired, however, such behaviour is a steel bar that will not bend. For some time birds have made use of this custom of earthworms to solve the problem of breakfast. The earthworms have persisted in their habits, not from a spirit of bravado, but simply because they are powerless to alter them. Nature will not alter them unless they are harmful on a large scale, and then only through the extermination of the worms as well as the habits.

The capacity for true thought is scarcely more conspicuous in animals with nervous endowments far greater than those of earthworms. If fishes possess intelligence, they must possess it in high degree to be able to hide all signs of it from the prying eye of the investigator. Amphibians are not much more satisfactory, although with superhuman patience a frog can be proved to possess a very slight ability to learn

from experience. Reptiles and birds, although richer in the range of their activities, are not distinguished for wit or moral strength. Only in the mammals can positive proof of memory, inference, and other marks of mentality be obtained. Yet even in this high society there are many disappointments. The guinea pig, pet of the experimenter, is as dull as a fish. The chimpanzee, on the other hand, is uncomfortably bright.

Despite the meagre display of mentality in most animals, there is a definite correlation between the excellence of their brains and the variety and complexity of their behaviour. A turtle leads a richer life than a herring, and a herring comes nearer to freedom than a worm. Although true intelligence flowers only in the brains of a few higher mammals and man, it is clearly akin to the more complex instincts. Both have grown with the growth of the brain. The roots of human mentality lie deep in the clay of past ages even though its branches stretch toward the sky.

We do not have to pry far into ourselves for the marks of our heritage. Libations of blood so recently poured at the feet of our brute instincts have not yet dried on the battlefields of Europe. And even in times of comparative peace—ignorance, prejudice, fear, custom, whimsy, and sentimentality guide the actions of men.

It is disconcerting to realize how much of the

behaviour of man is of purely instinctive origin, behaviour which though always flowing from the nervous system, and often complicated, is no more intelligent than the performance of an adding machine. I cough, breathe, and digest food just as unconsciously and unwilfully as any animal. Like an animal I respond to the urge to protect myself and to reproduce. In countless ways I am controlled by the herd with which I run. A sheep starves if he strays from the pack, and I am ridiculed if I wear a straw hat in January.

But the slow bulging and wrinkling of the cerebrum did more than imbed the blind instincts of the past. It nursed the seeds of a richer future. There are weeds in the soil where mentality grows, but the gardener who knows them can keep them in check even if he fails to exterminate them. The hope of man lies in the fact that he has been appointed gardener to his own destiny. The spade and trowel of intelligence have been in his hands for more than twenty thousand years. Although he has used them with little knowledge of what he hoped to accomplish, language has somehow grown in his garden and from it the fruits of art and science. Only now is man beginning to know how to direct his tools to a conscious purpose. He has begun to learn how to control some of the forces in the environment, and it is not presumptuous to hope that he may learn to control more effectively the instinctive emotional forces within himself.

Even though man may never hope for better tools than he now has, he may hope for more knowledge of how to use them. There may never come a finer Michelangelo, Dante, Darwin, or Christ, but there is plenty of room for a wider dissemination of their powers, for a richer mental and emotional life in each individual.

Man has travelled a long distance without consciously directing his footsteps. Nature has done fairly well by him. She has imposed many handicaps but she has given him, alone among her swarming brood, an intelligence to counterbalance. He has not yet begun to climb the heights of mental and spiritual development. If he does not reach the moon it will be his own fault.

THE END